US007127191B2

(12) **United States Patent**
Mori et al.

(10) **Patent No.: US 7,127,191 B2**
(45) **Date of Patent: Oct. 24, 2006**

(54) **CLEANING DEVICE FOR COLLECTING TONER ON A SURFACE OF AN IMAGE FORMING APPARATUS**

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(73) Assignee: **Konica Minolta Business Technologies, Inc.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 47 days.

(21) Appl. No.: **10/809,786**

(22) Filed: **Mar. 26, 2004**

(65) **Prior Publication Data**

US 2004/0213598 A1 Oct. 28, 2004

(30) **Foreign Application Priority Data**

Mar. 26, 2003	(JP)	....	2003-085261
Feb. 27, 2004	(JP)	....	2004-053834
Feb. 27, 2004	(JP)	....	2004-054334

(51) **Int. Cl.**
G03G 15/16 (2006.01)

(52) **U.S. Cl.** **399/101**

(58) **Field of Classification Search** 399/101, 399/302, 343, 349, 353, 354, 357

See application file for complete search history.

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Assistant Examiner—Dixomara Vargas
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(57) **ABSTRACT**

A cleaning device is provided with a conductive fur brush kept in contact with a transfer belt, a conductive brush kept in contact with the transfer belt upstream of the fur brush in the feed direction, and a single of constant-current d.c. power supply. The fur brush is connected to the constant-current d.c. power supply, and the conductive brush is grounded. A current flows from the constant-current d.c. power supply via the transfer belt to the conductive brush.

8 Claims, 30 Drawing Sheets

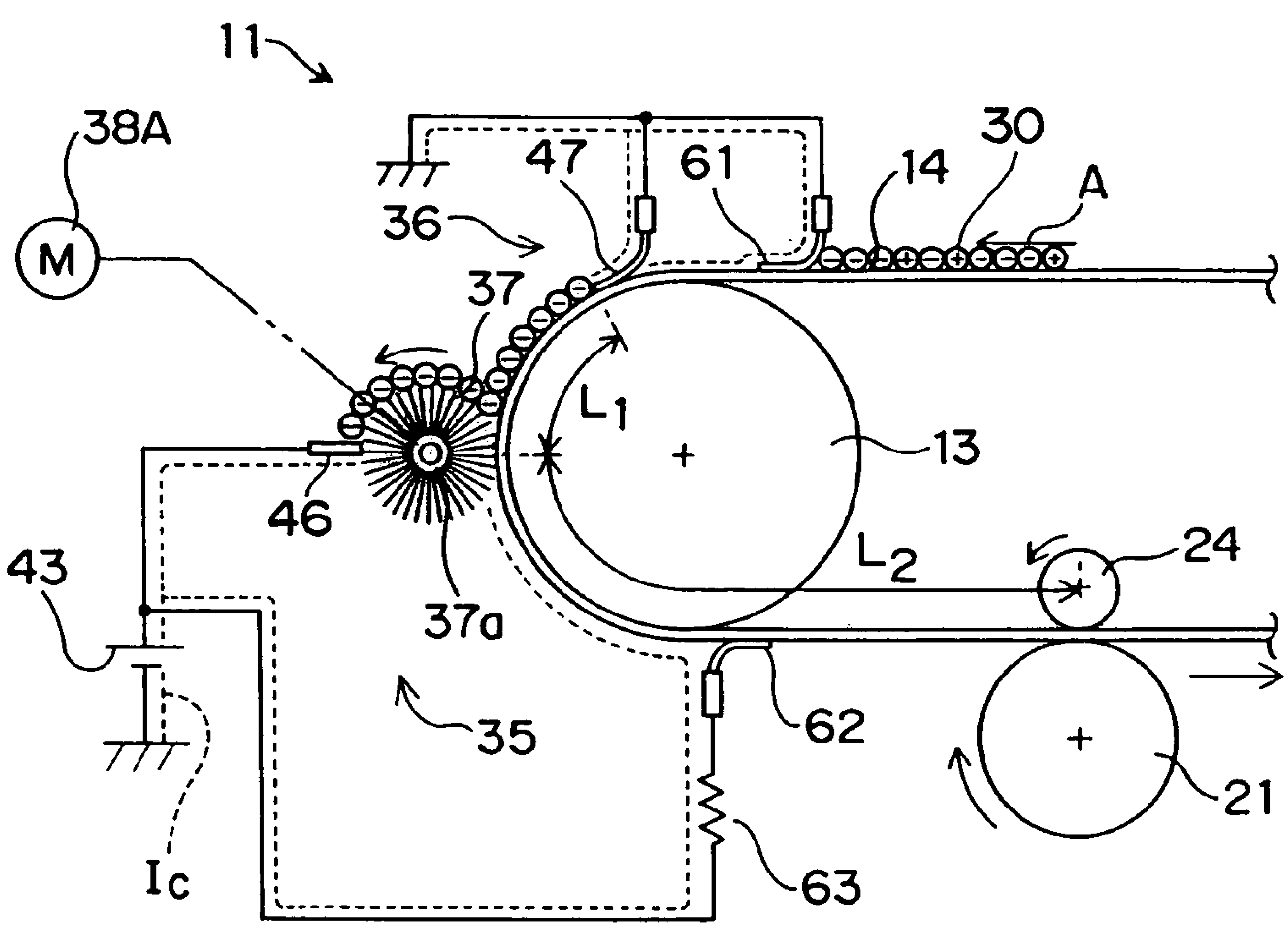


Fig. 1

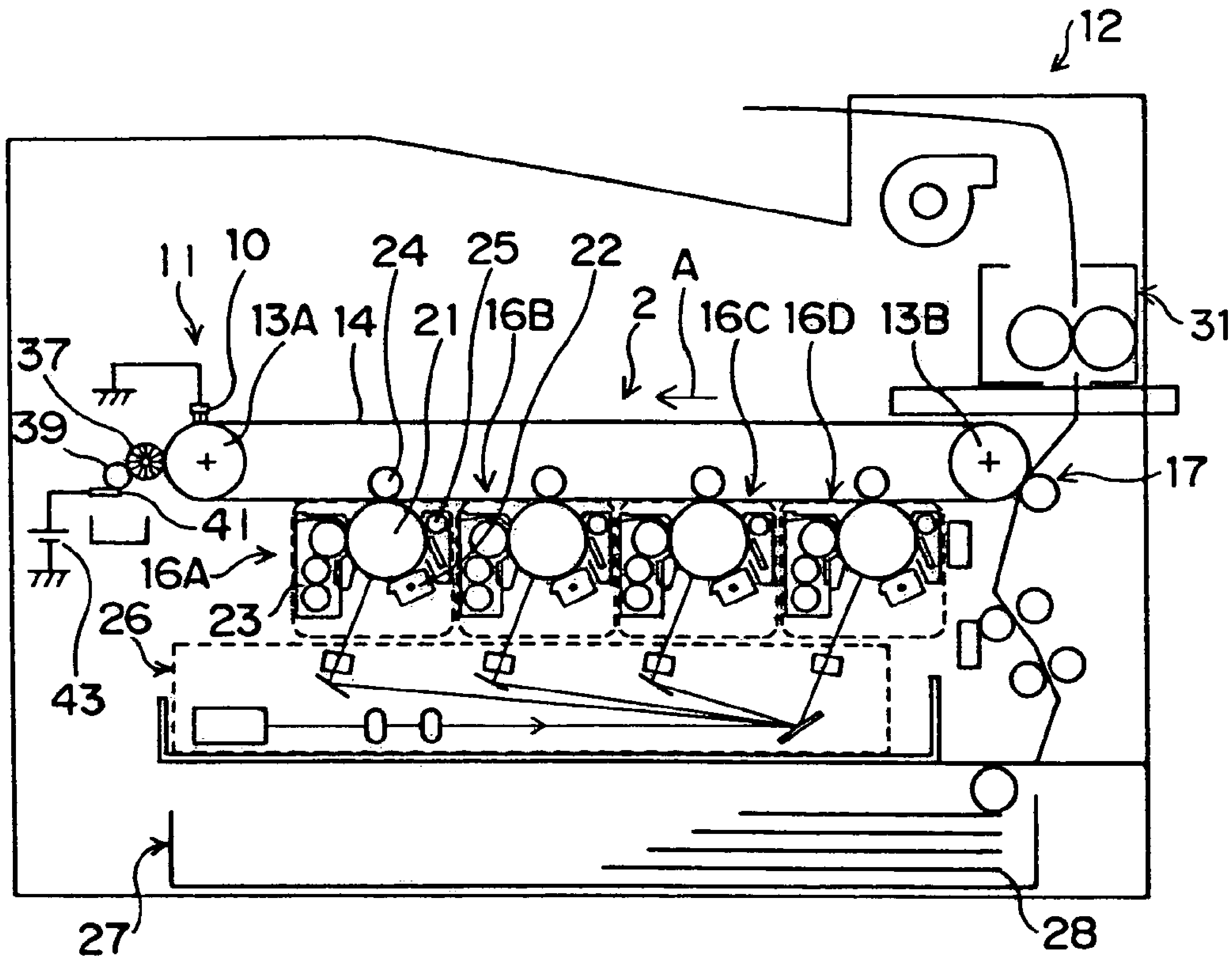

12
11
10
24
25
22
A
37
13A
14
21
16B
2
16C
16D
13B
31
39
17
41
16A
23
26
43
27
28

Fig. 2

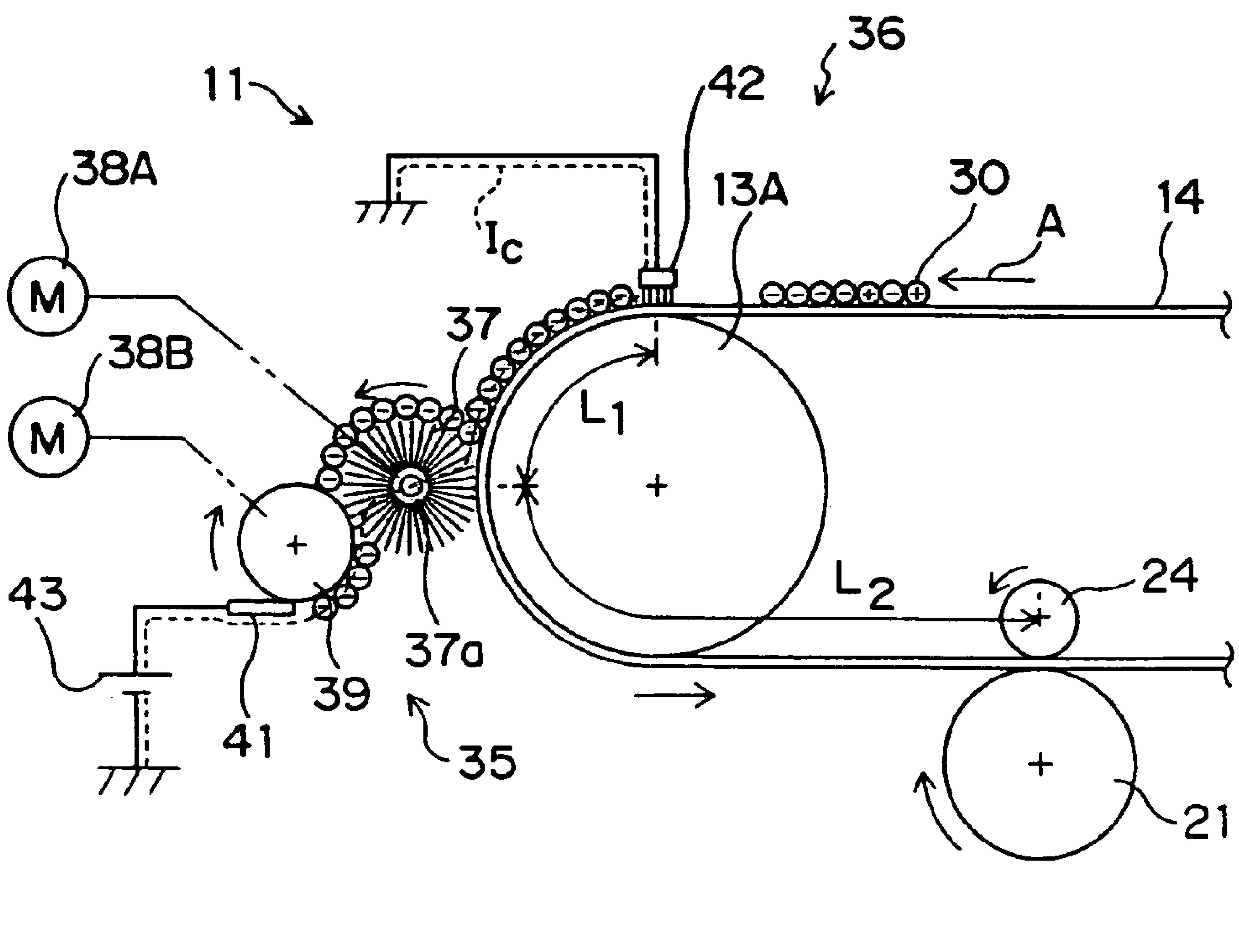

36
11
42
38A
13A
30
A
14
I_c
M
37
38B
M
L_1
L_2
24
43
39
37a
41
35
21

Fig. 3

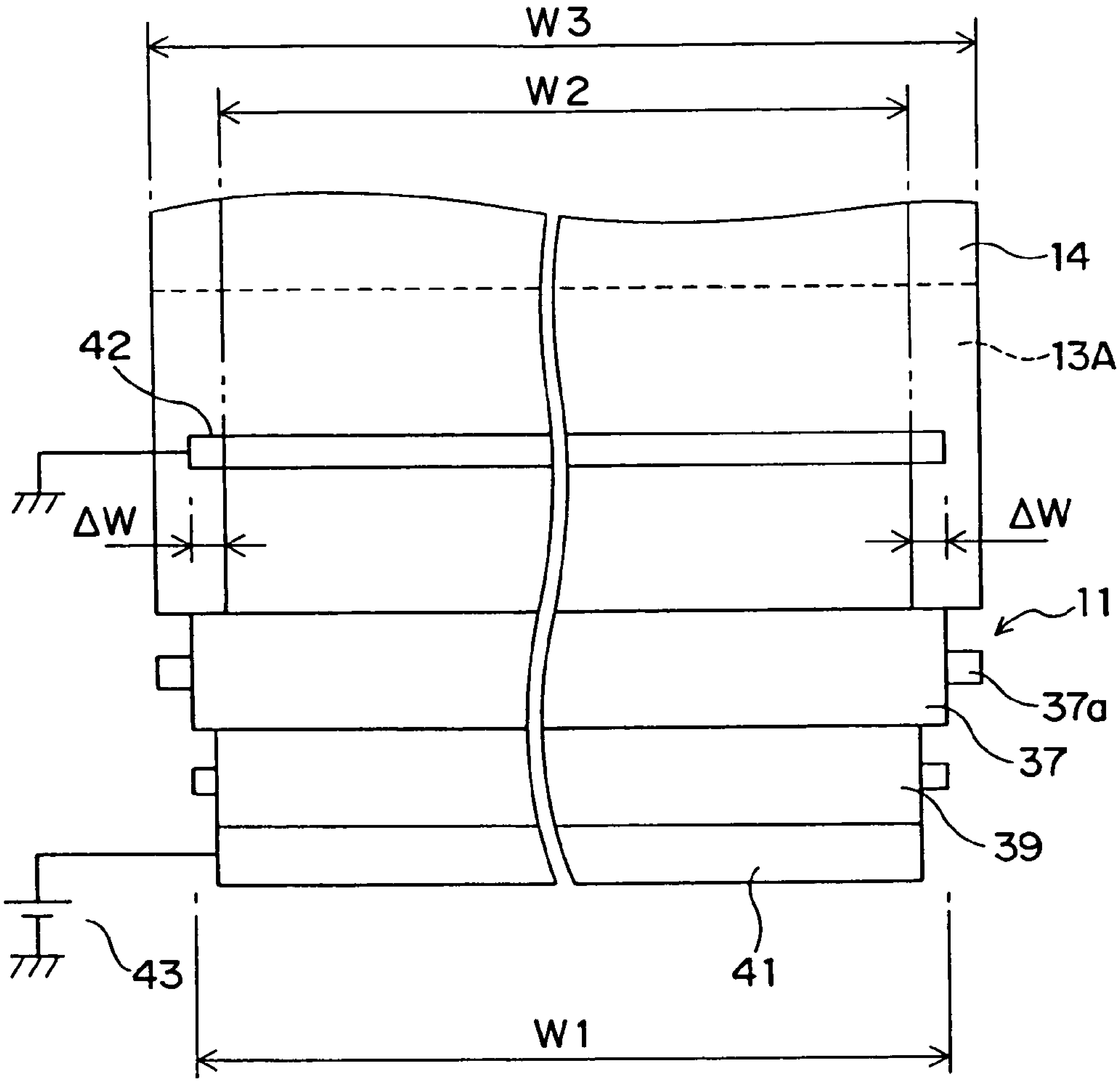


Fig.4

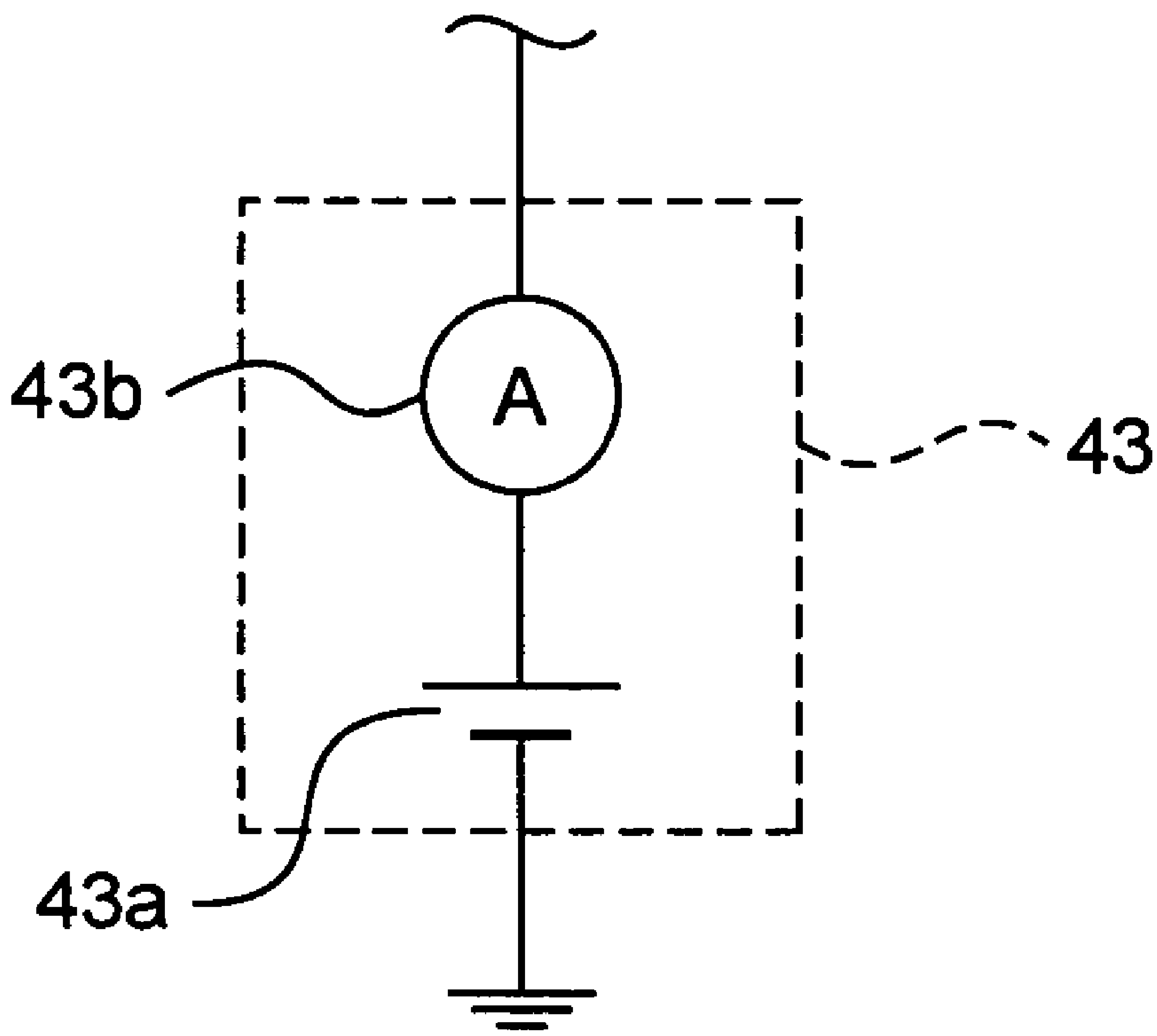


Fig. 5A

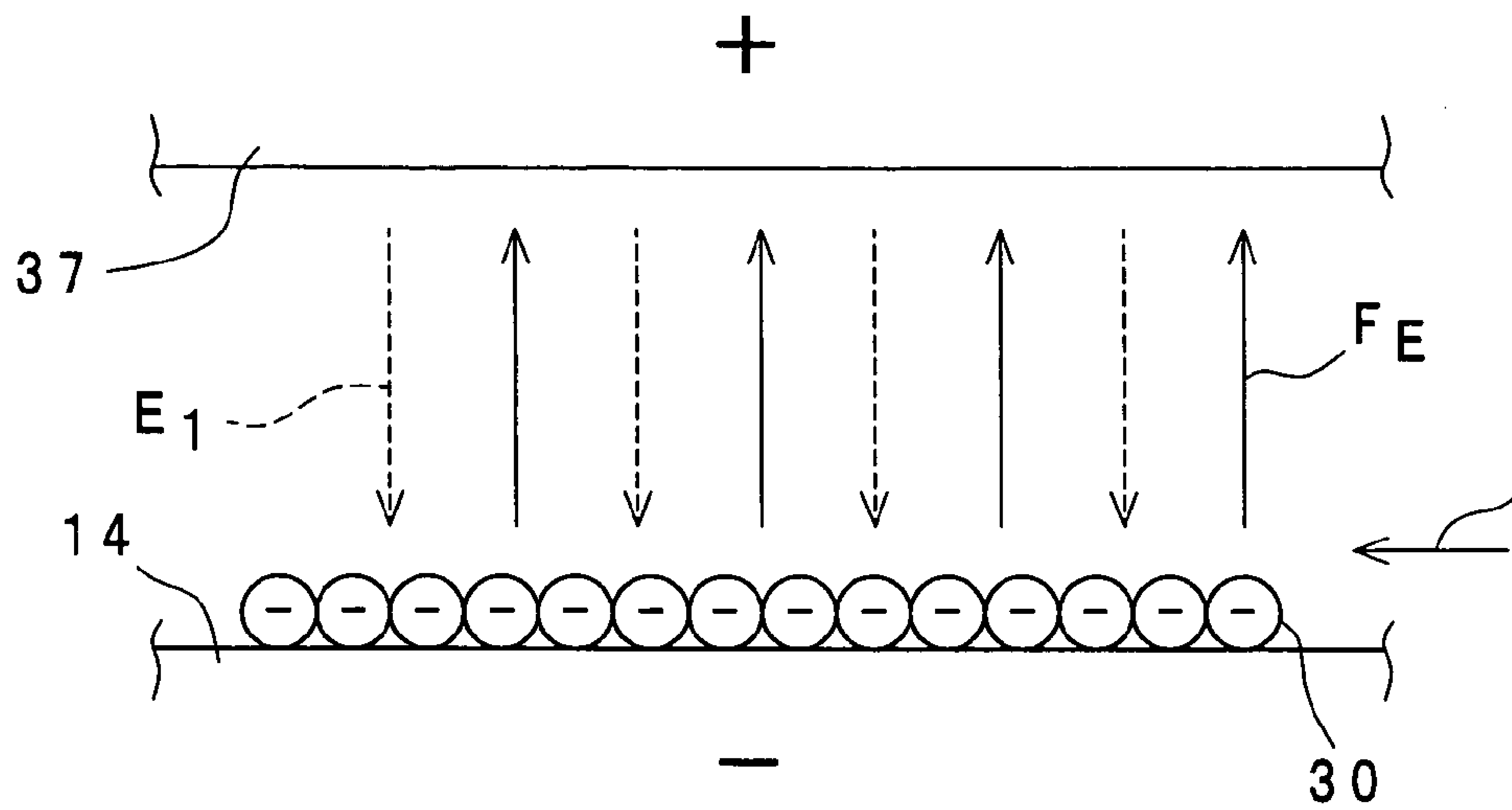


Fig. 5B

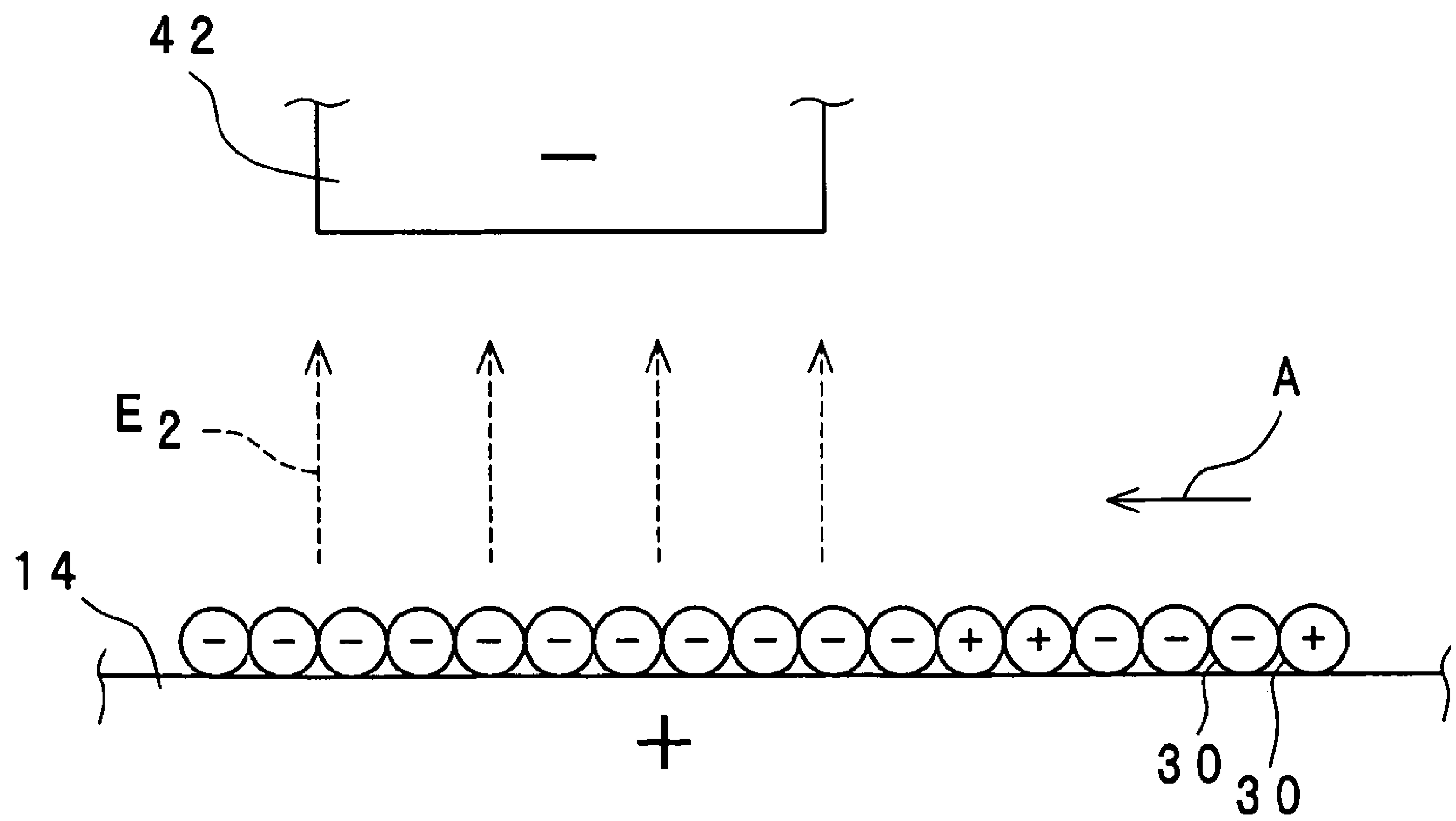


Fig. 6

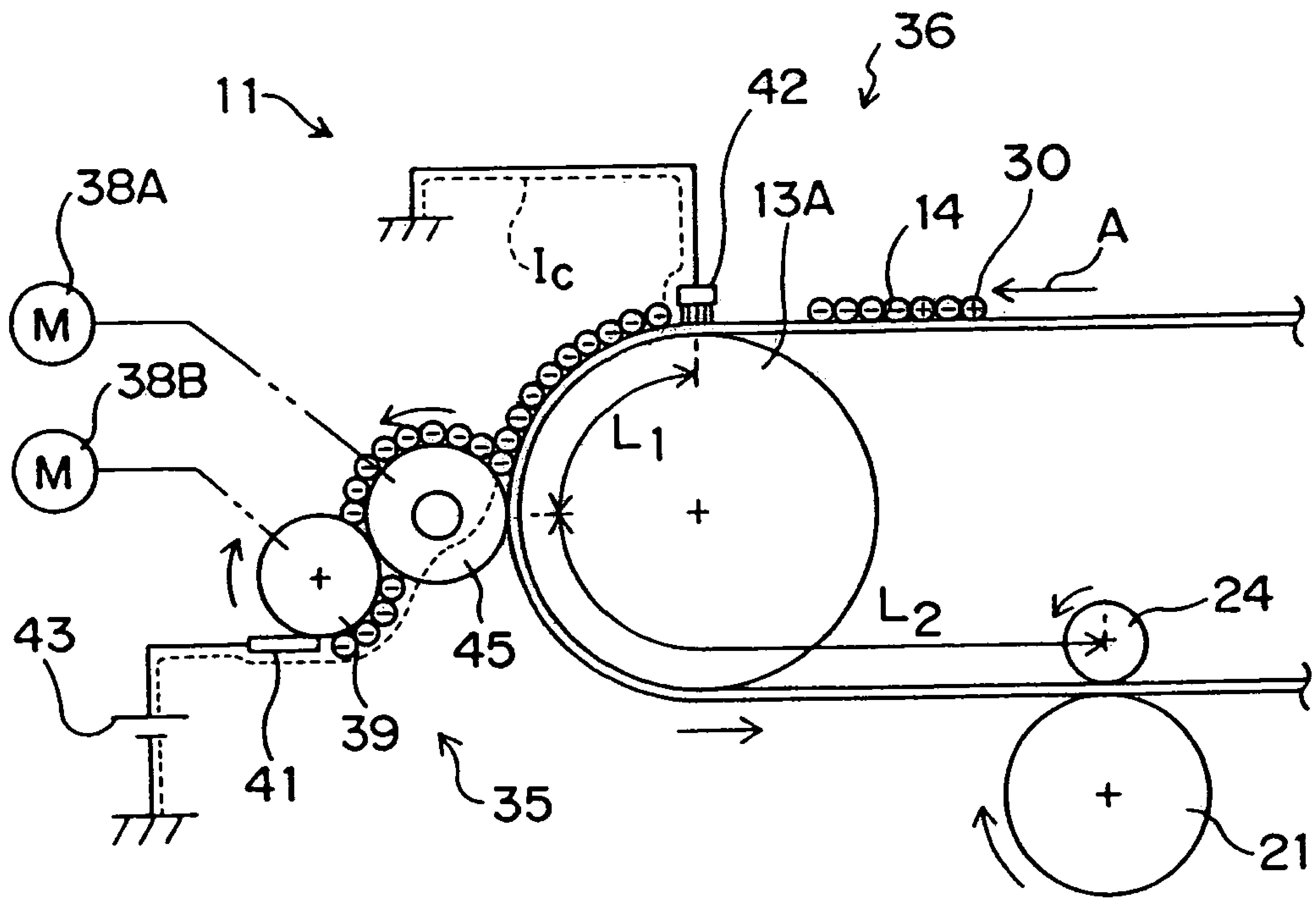


Fig. 7

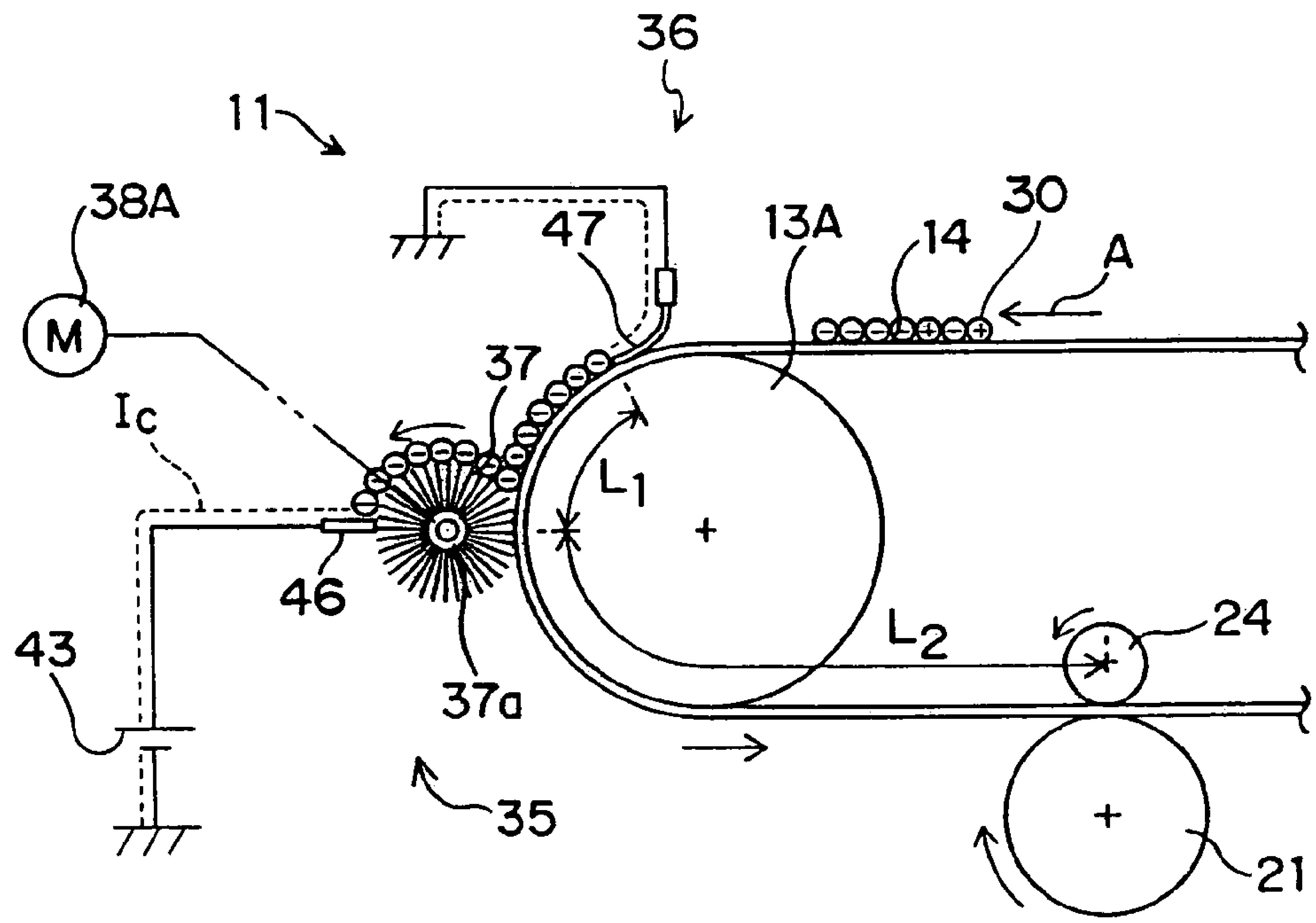


Fig. 8

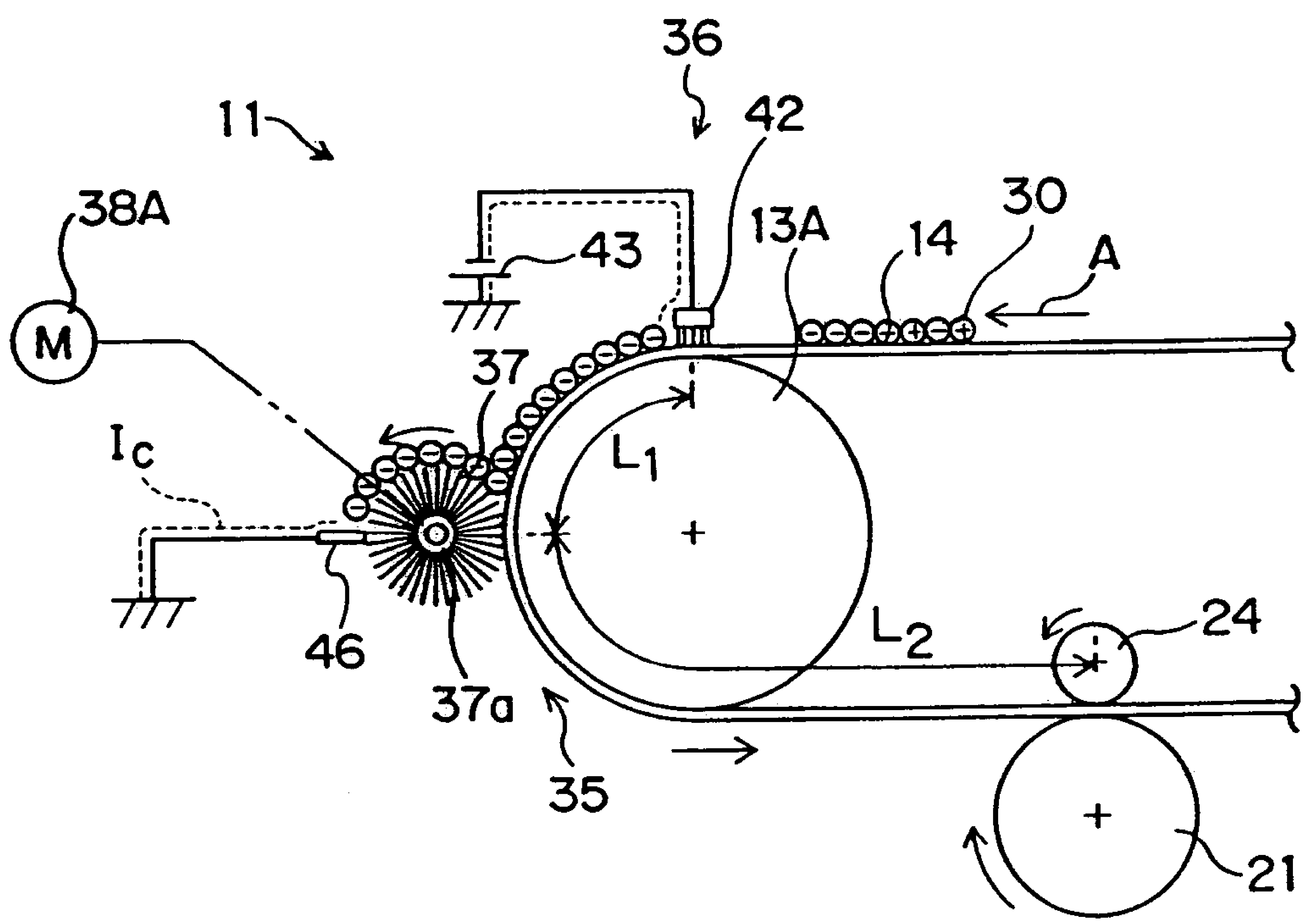


Fig. 9

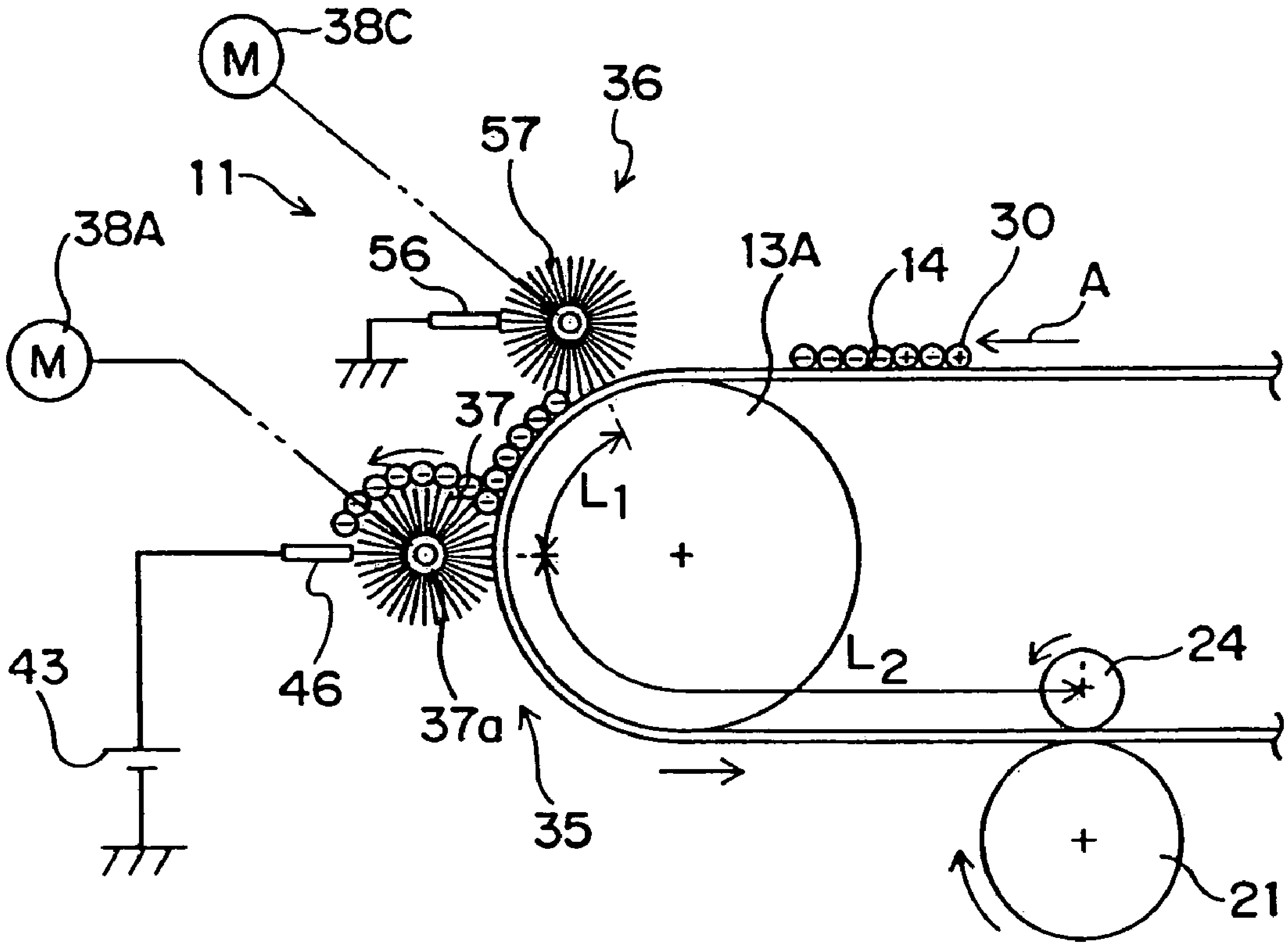


Fig. 10

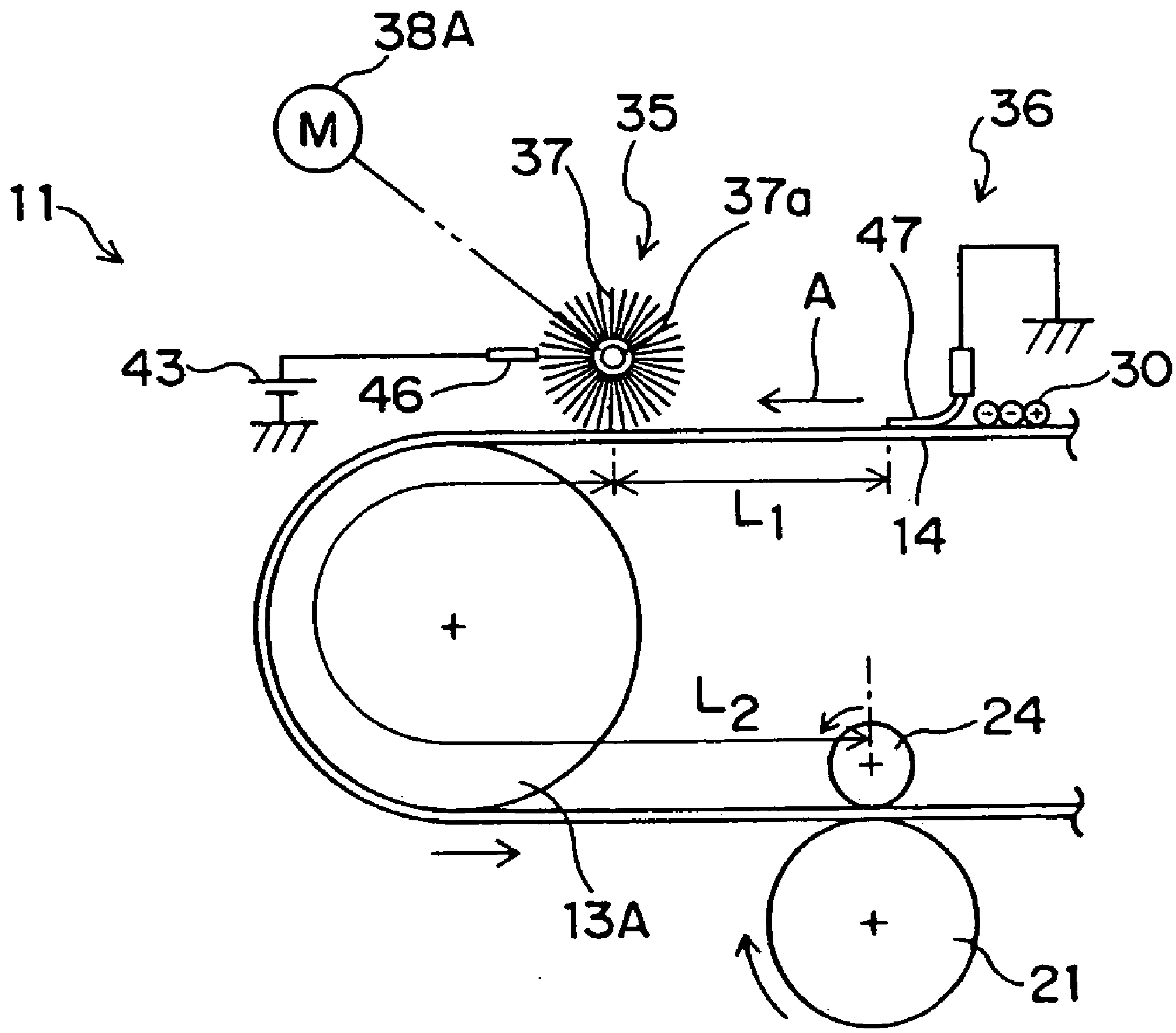


Fig. 11

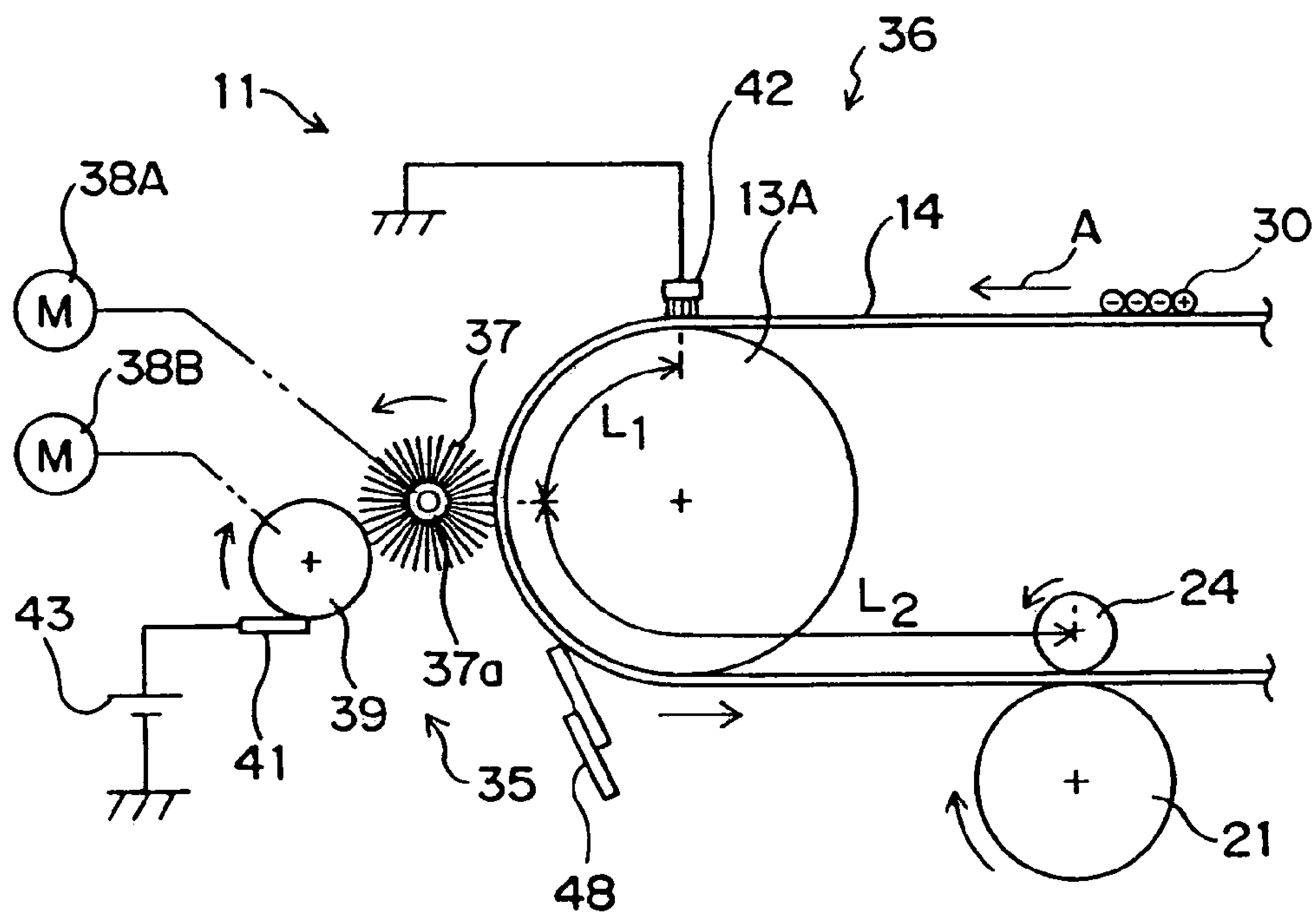


Fig. 12

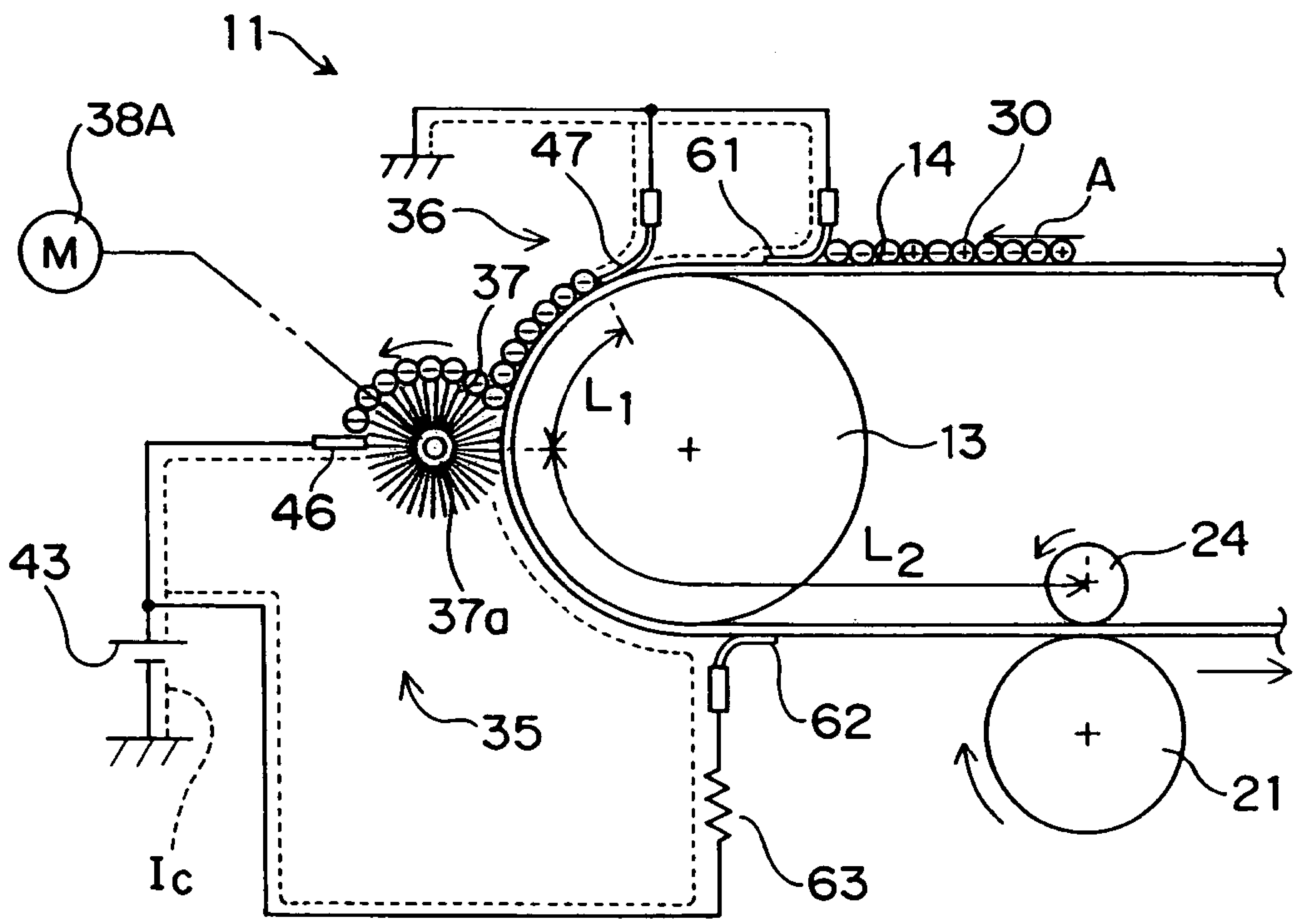


Fig. 13

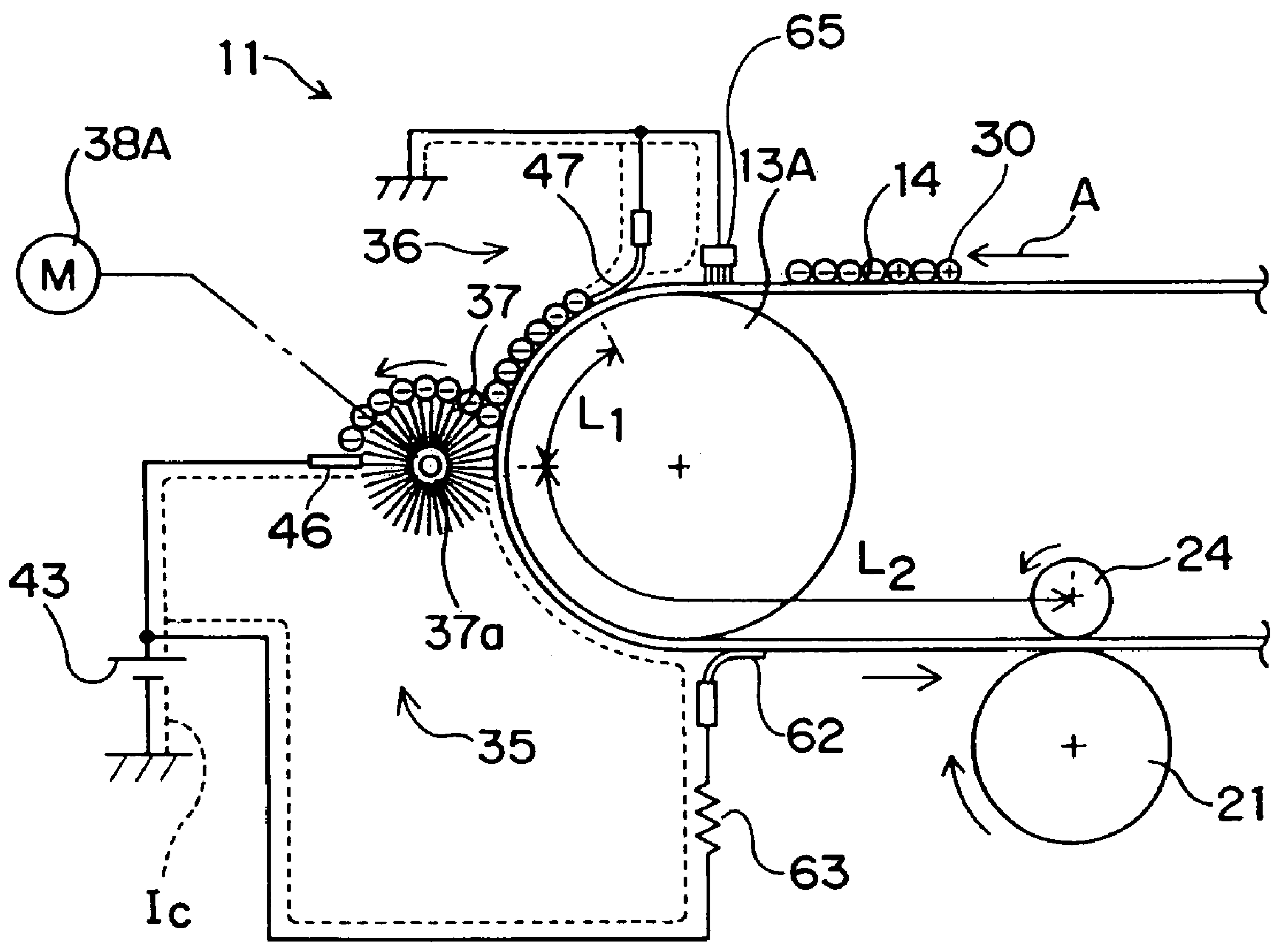


Fig. 14

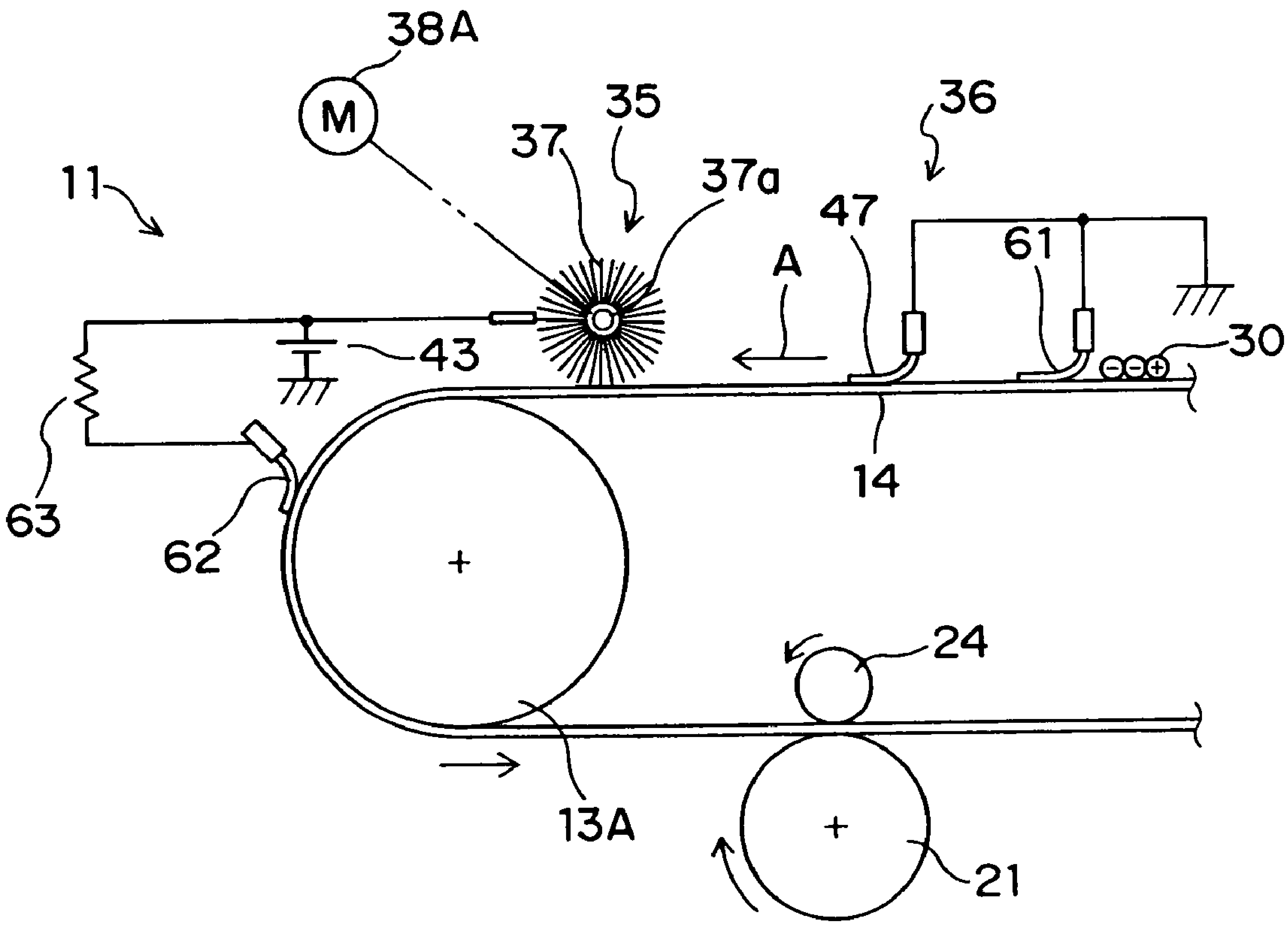
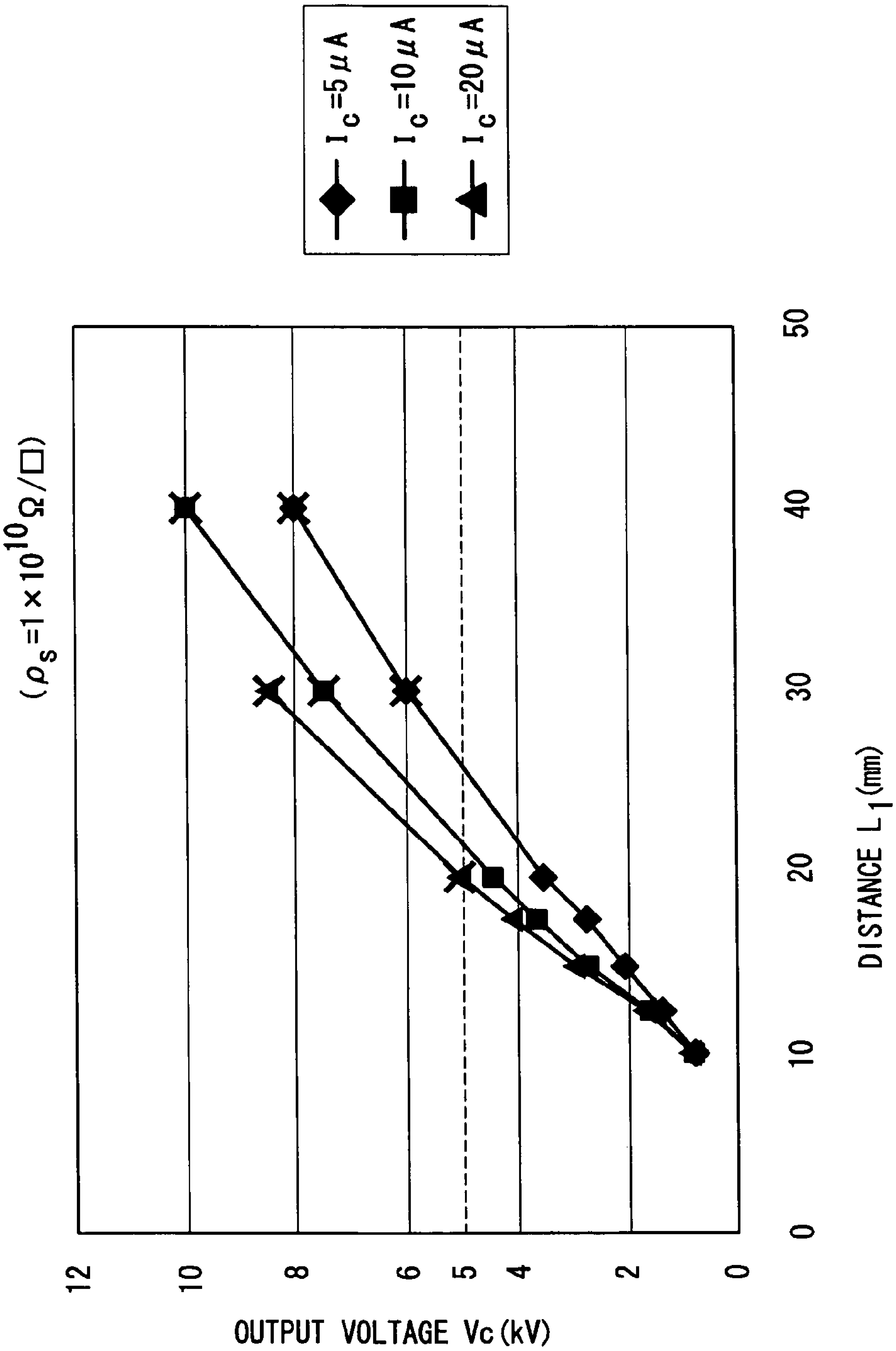


Fig. 15



(ρ_s=1×10^{10}Ω/□)
I_c=5μA
I_c=10μA
I_c=20μA
OUTPUT VOLTAGE Vc(kV)
DISTANCE L_1(mm)
0
2
4
5
6
8
10
12
0
10
20
30
40
50

Fig. 16

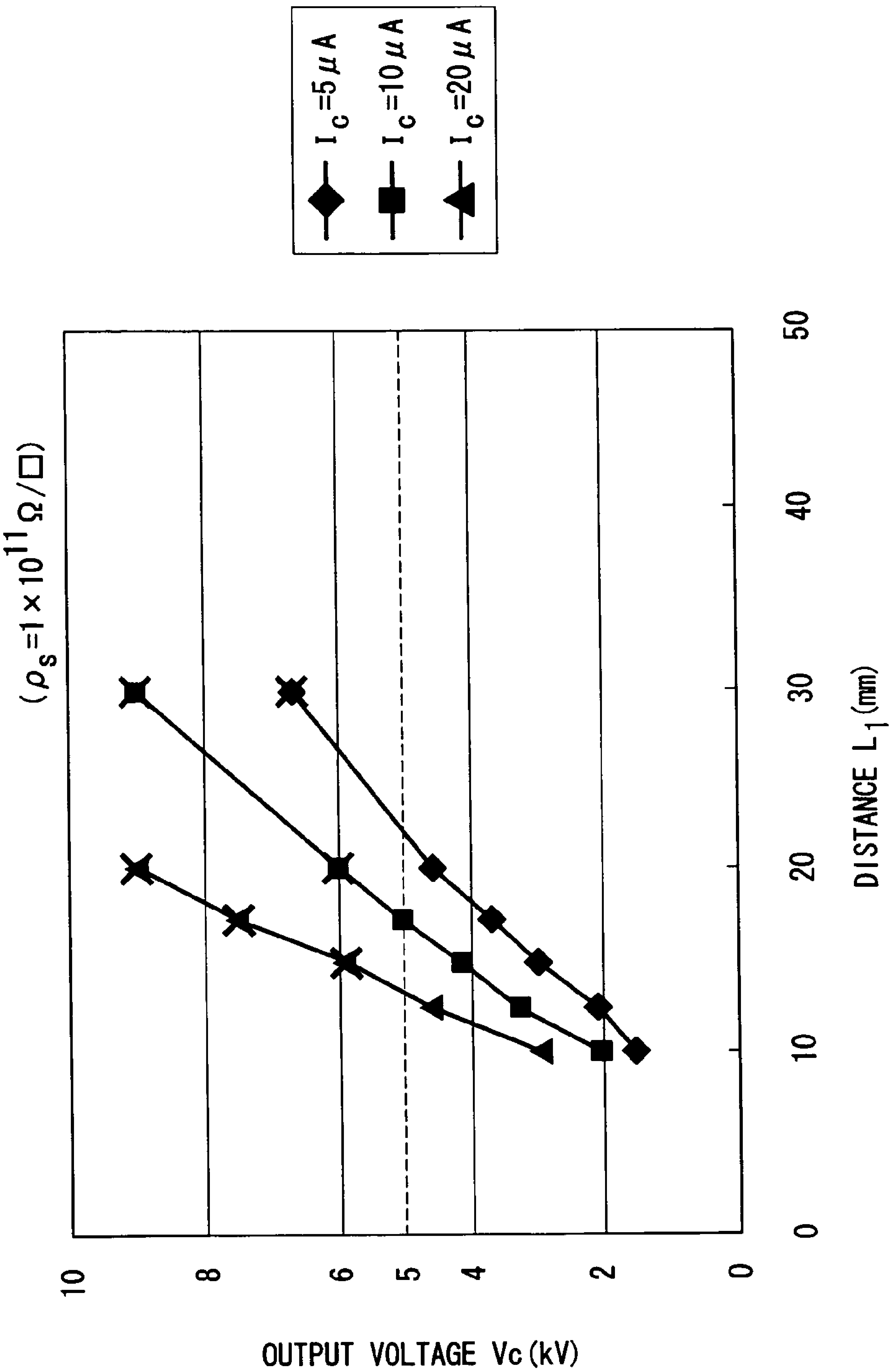

I_c=5μA
I_c=10μA
I_c=20μA
(ρ_s=1×10^{11}Ω/□)
OUTPUT VOLTAGE Vc (kV)
0
2
4
5
6
8
10
DISTANCE L_1 (mm)
0
10
20
30
40
50

Fig. 17

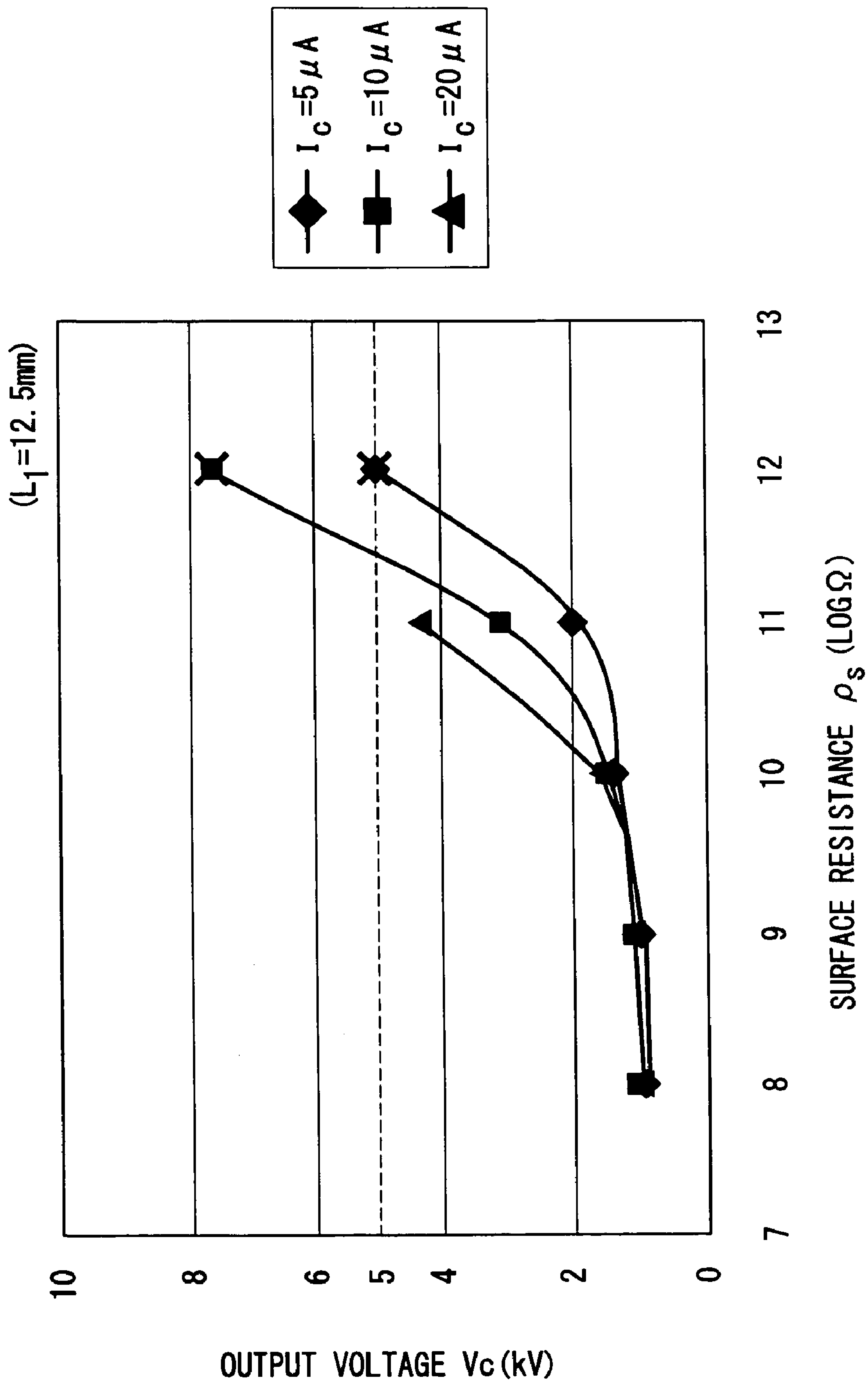
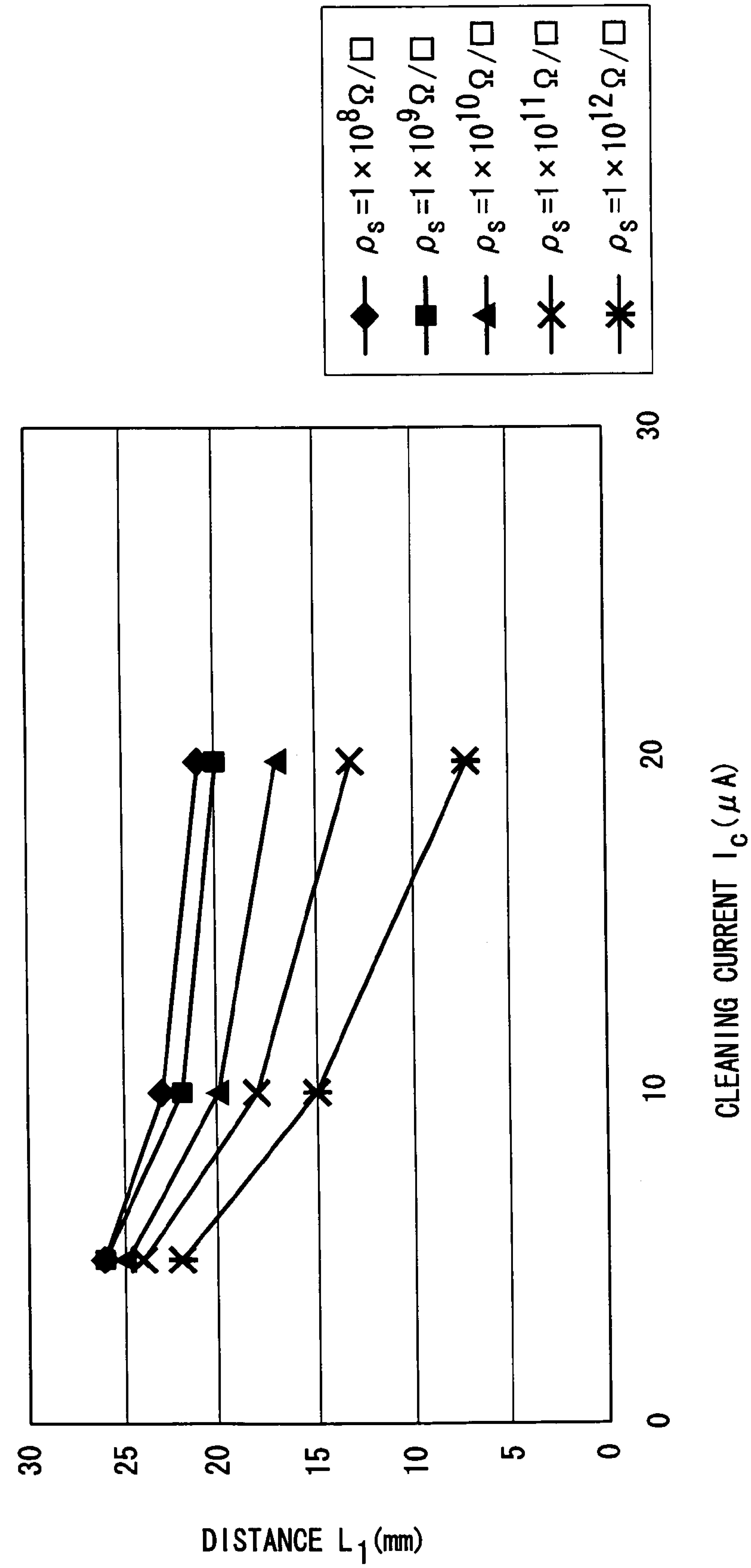

(L1=12. 5mm)
OUTPUT VOLTAGE Vc(kV)
10
8
6
5
4
2
0
7
8
9
10
11
12
13
SURFACE RESISTANCE ρs (LOGΩ)
Ic=5μA
Ic=10μA
Ic=20μA

Fig. 18



DISTANCE L_1(mm)
30
25
20
15
10
5
0
10
20
30
CLEANING CURRENT I_c(μA)
ρ_s=1×10^{8}Ω/□
ρ_s=1×10^{9}Ω/□
ρ_s=1×10^{10}Ω/□
ρ_s=1×10^{11}Ω/□
ρ_s=1×10^{12}Ω/□

Fig. 19

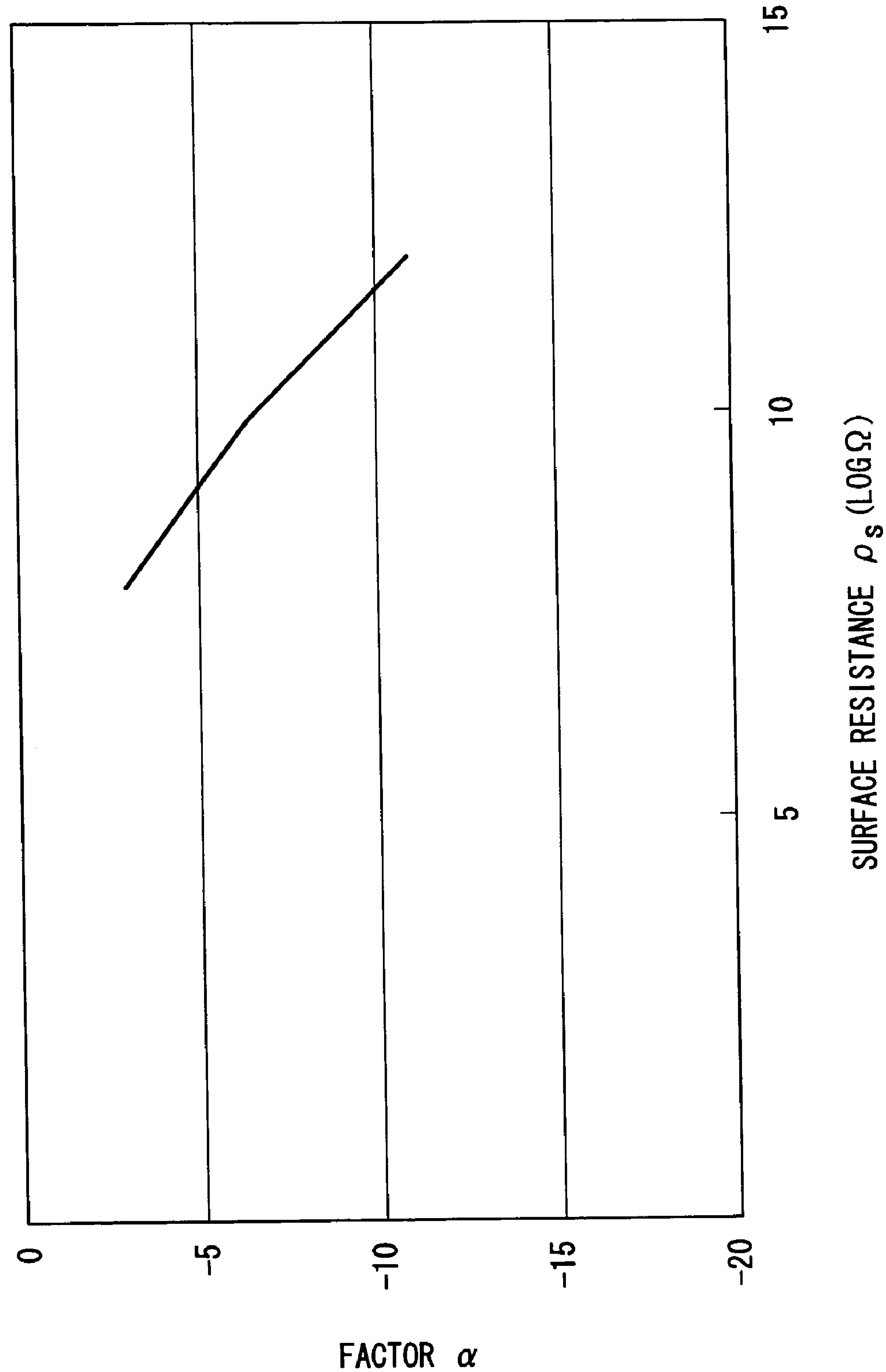


Fig. 20

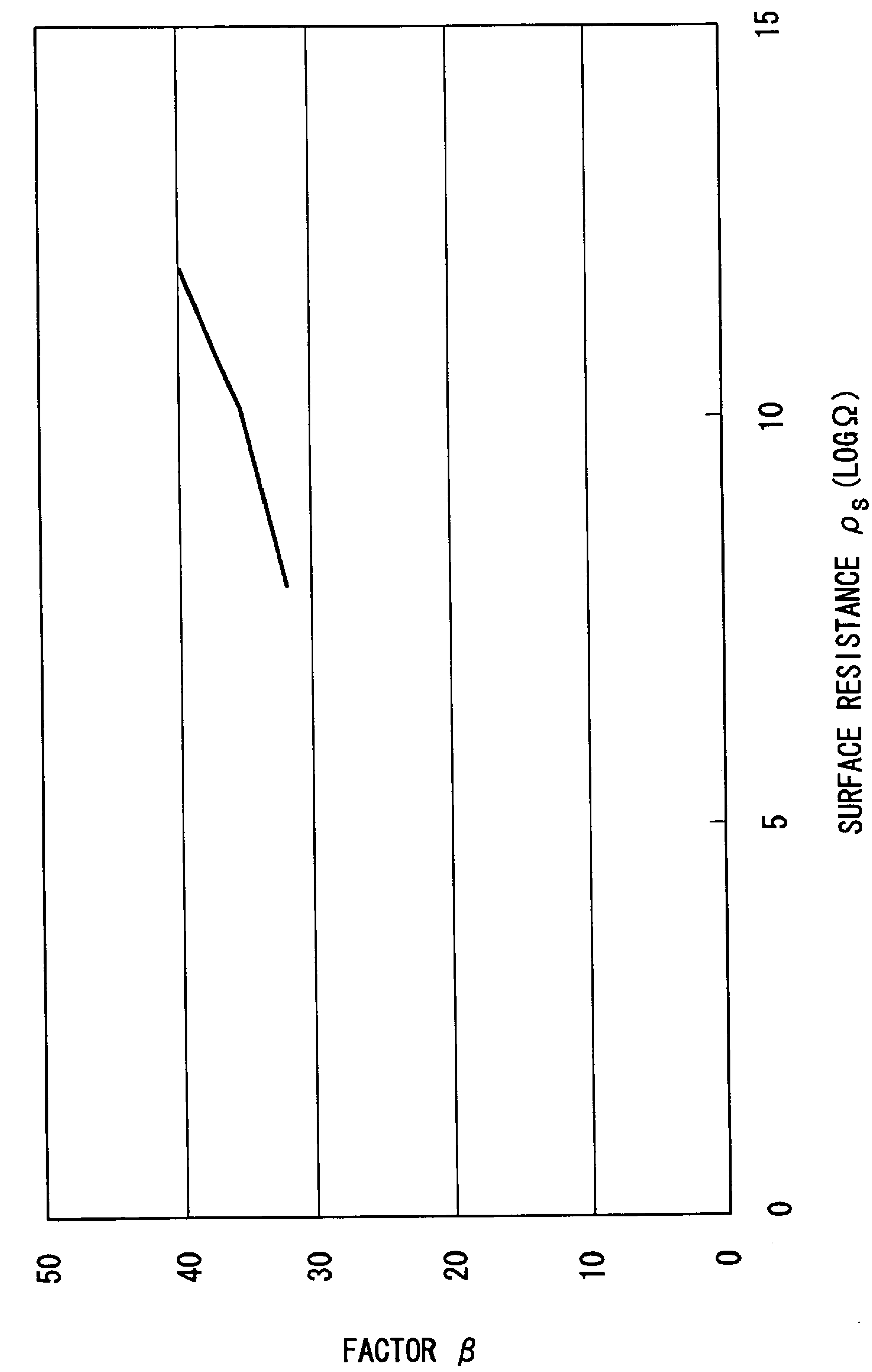
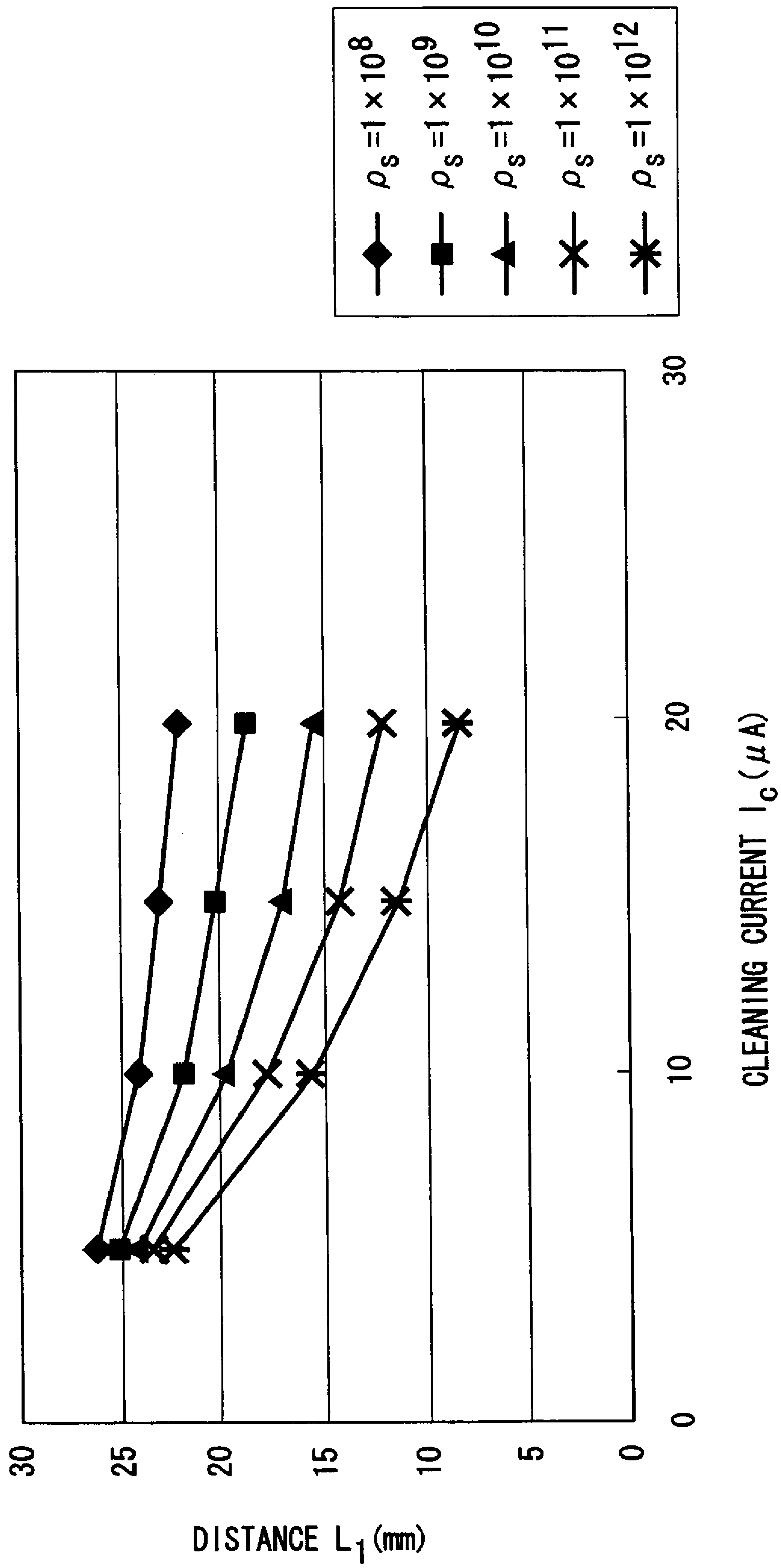


Fig. 21



DISTANCE L_1 (mm)
CLEANING CURRENT I_C (μA)
0
5
10
15
20
25
30
0
10
20
30
ρ_S=1×10^8
ρ_S=1×10^9
ρ_S=1×10^{10}
ρ_S=1×10^{11}
ρ_S=1×10^{12}

Fig. 22

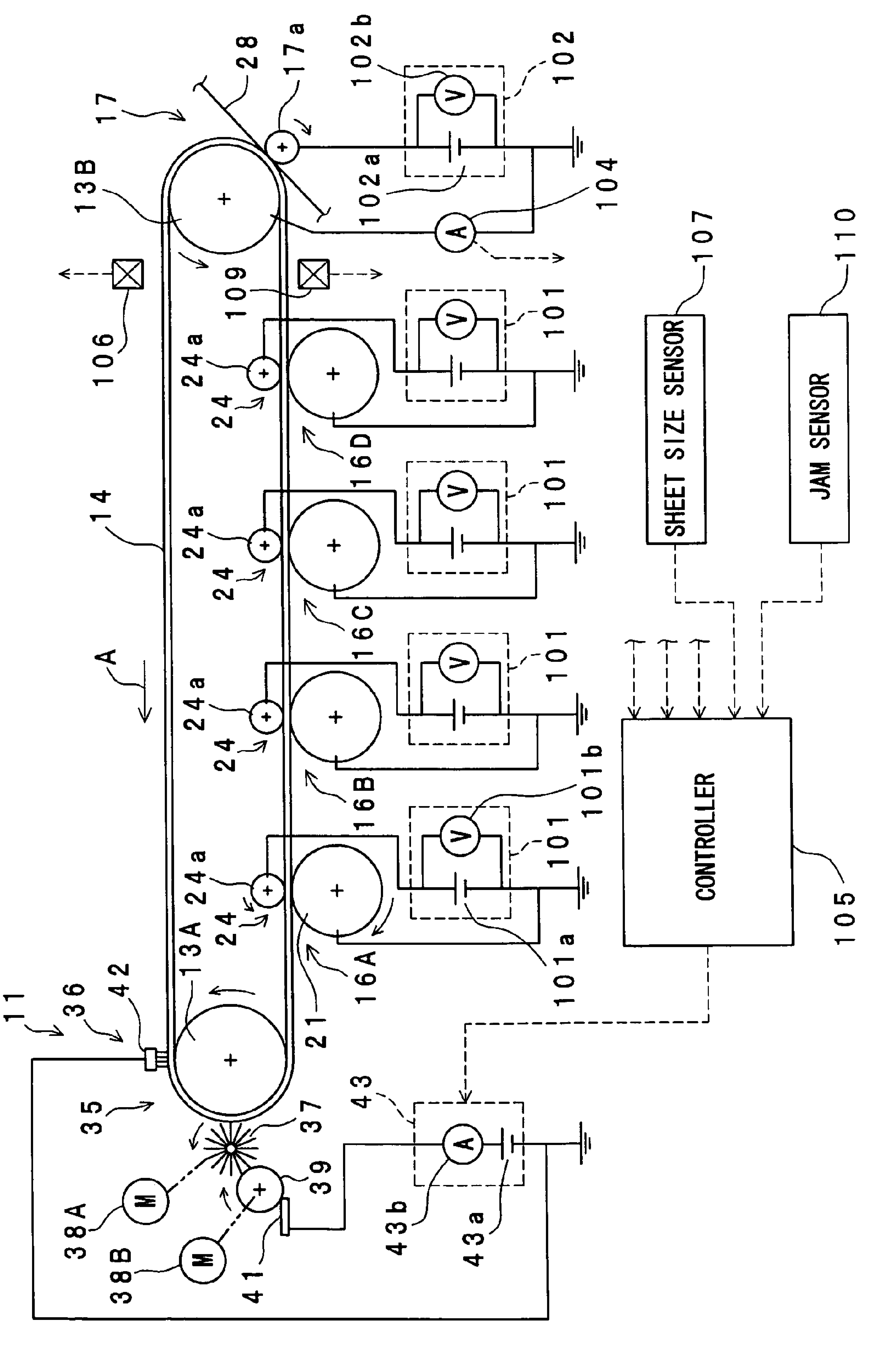

SHEET SIZE SENSOR
JAM SENSOR
CONTROLLER
11
13A
13B
14
16A
16B
16C
16D
17
17a
21
24
24a
28
35
36
37
38A
38B
39
41
42
43
43a
43b
101
101a
101b
102
102a
102b
104
105
106
107
109
110
A
M
V

Fig. 23A

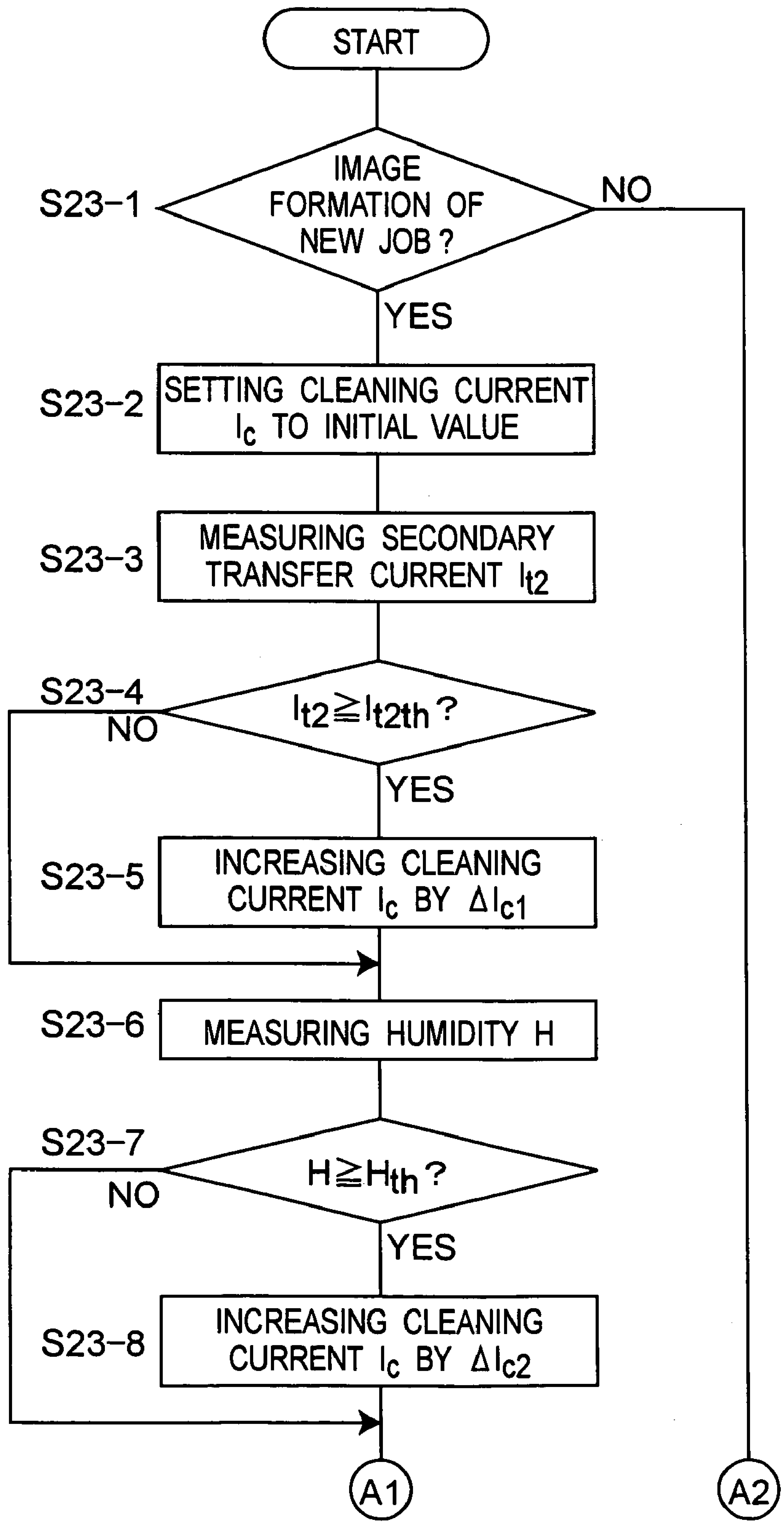
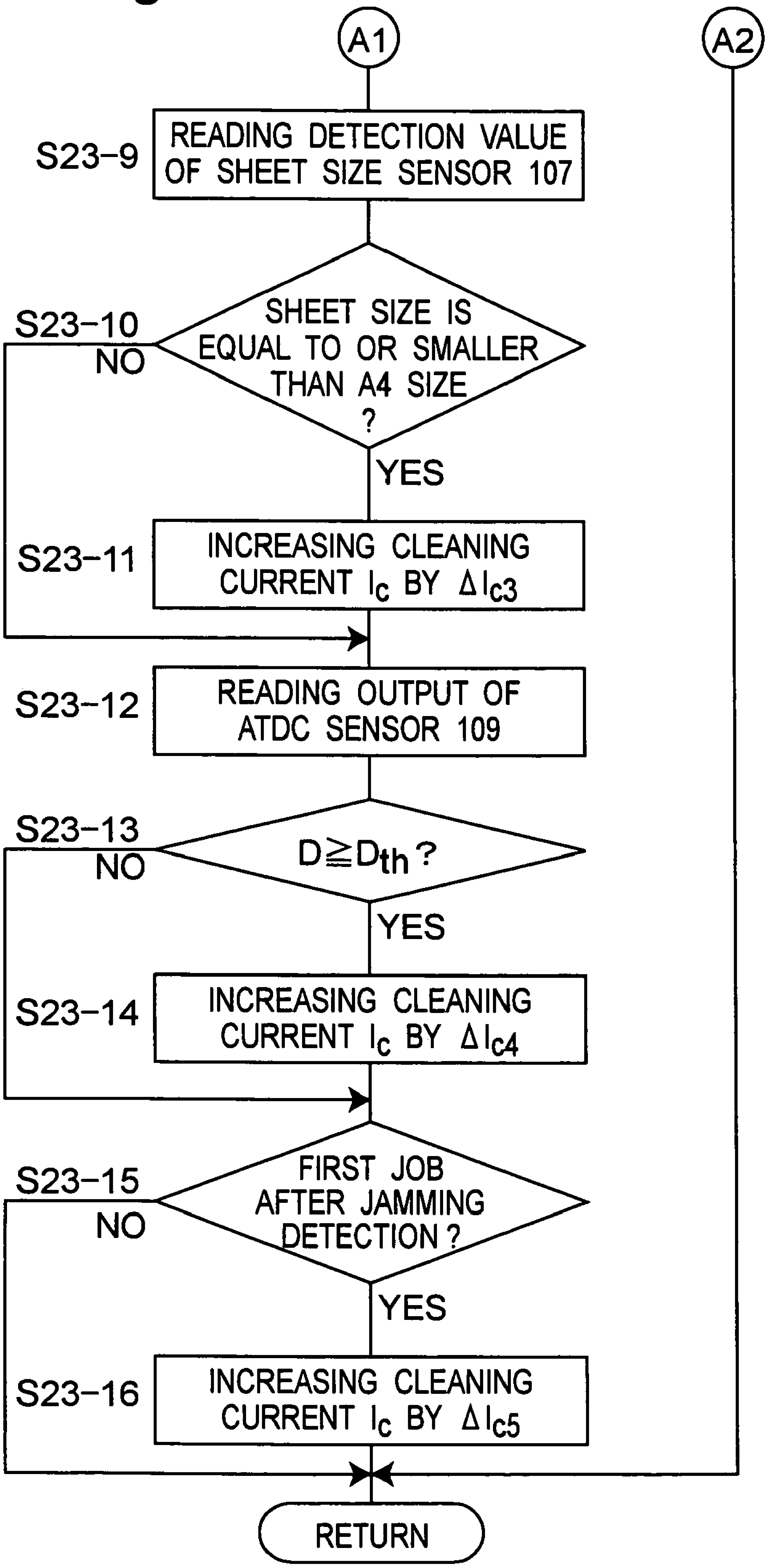

START
S23-1
IMAGE FORMATION OF NEW JOB ?
NO
YES
S23-2
SETTING CLEANING CURRENT I_c TO INITIAL VALUE
S23-3
MEASURING SECONDARY TRANSFER CURRENT I_{t2}
S23-4
$I_{t2} \geqq I_{t2th}$?
NO
YES
S23-5
INCREASING CLEANING CURRENT I_c BY ΔI_{c1}
S23-6
MEASURING HUMIDITY H
S23-7
$H \geqq H_{th}$?
NO
YES
S23-8
INCREASING CLEANING CURRENT I_c BY ΔI_{c2}
A1
A2

Fig.23B



A1
A2
S23-9
READING DETECTION VALUE OF SHEET SIZE SENSOR 107
S23-10
SHEET SIZE IS EQUAL TO OR SMALLER THAN A4 SIZE ?
NO
YES
S23-11
INCREASING CLEANING CURRENT Ic BY ΔIc3
S23-12
READING OUTPUT OF ATDC SENSOR 109
S23-13
D≧Dth ?
NO
YES
S23-14
INCREASING CLEANING CURRENT Ic BY ΔIc4
S23-15
FIRST JOB AFTER JAMMING DETECTION ?
NO
YES
S23-16
INCREASING CLEANING CURRENT Ic BY ΔIc5
RETURN

Fig.24A

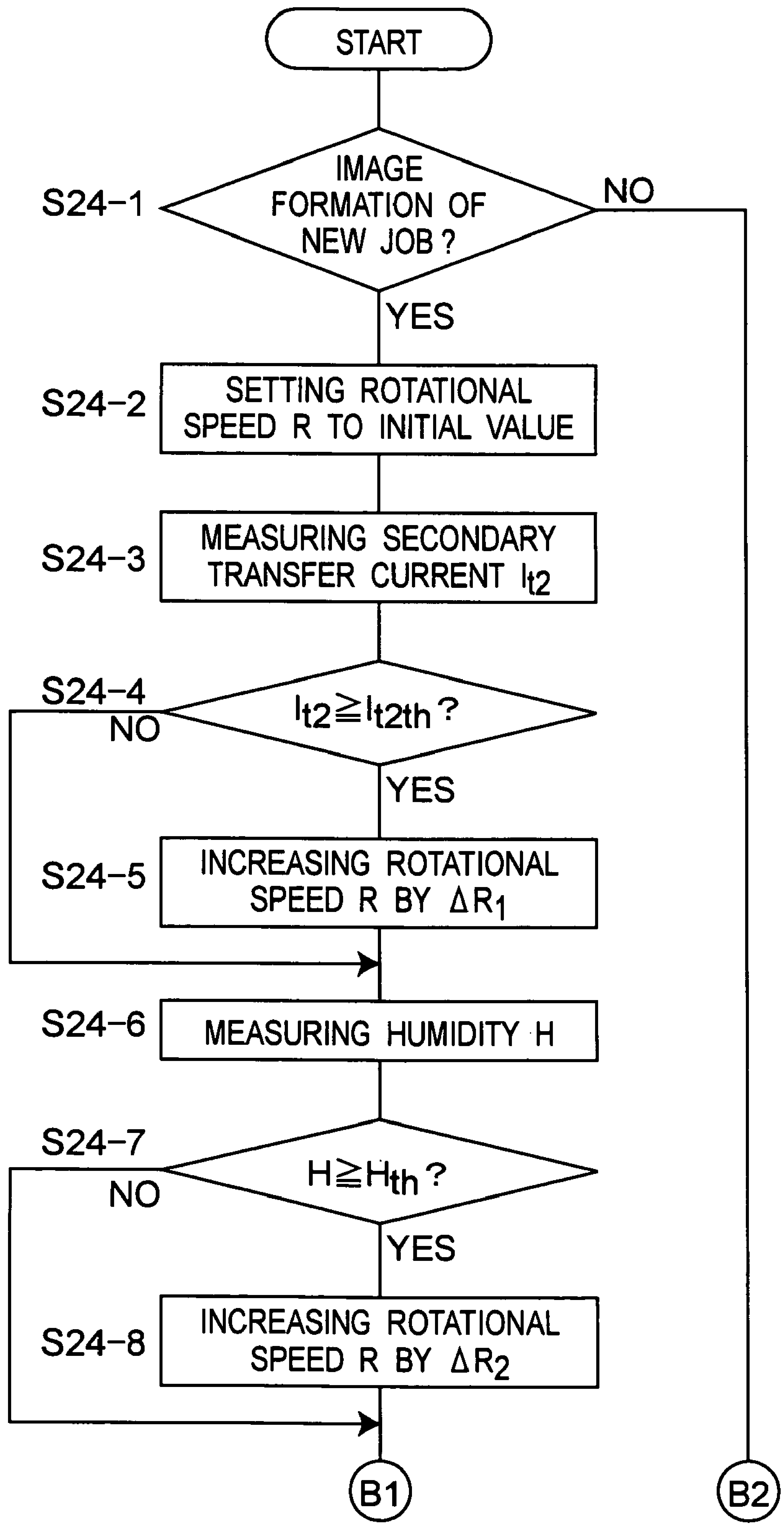
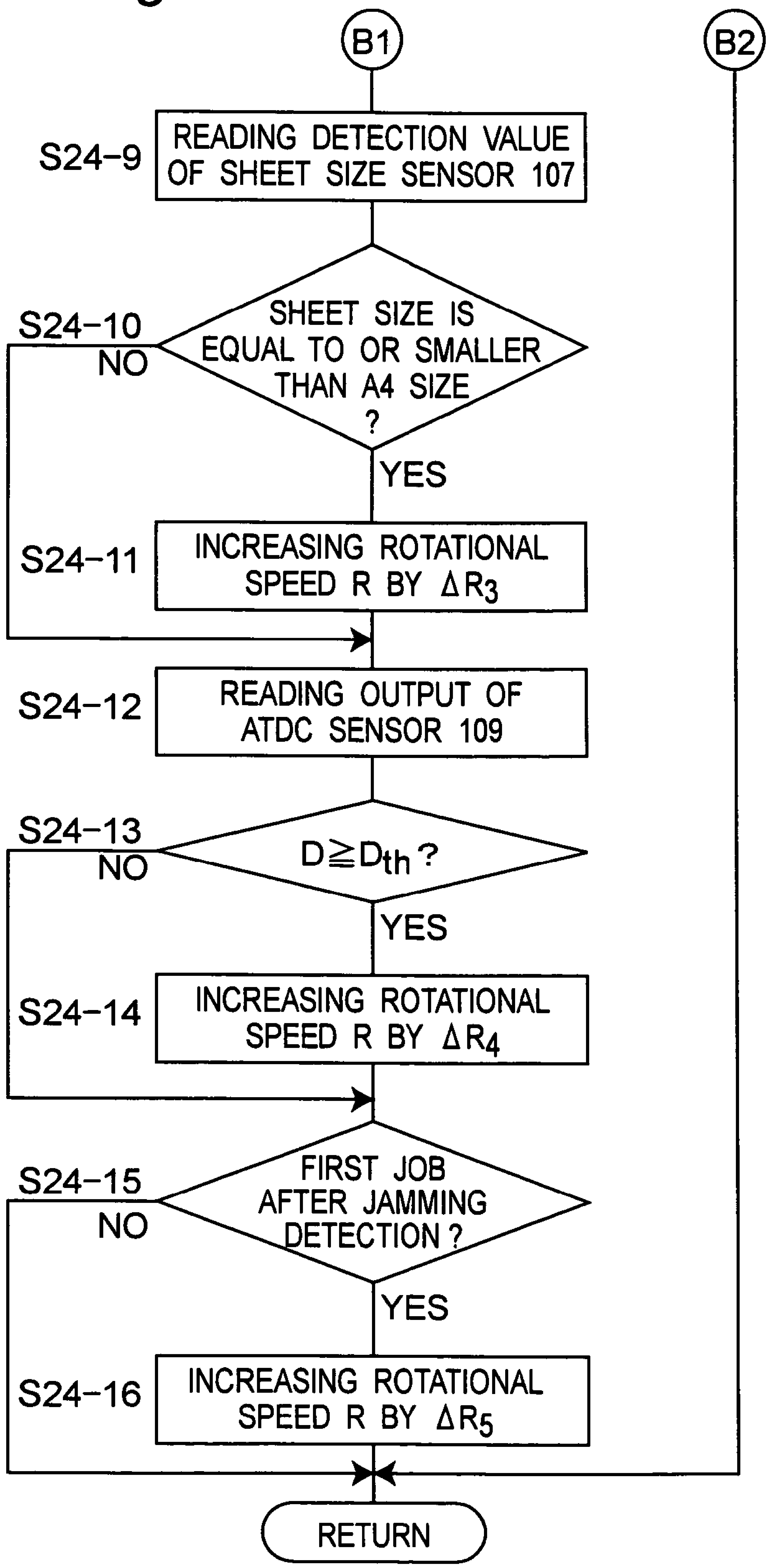
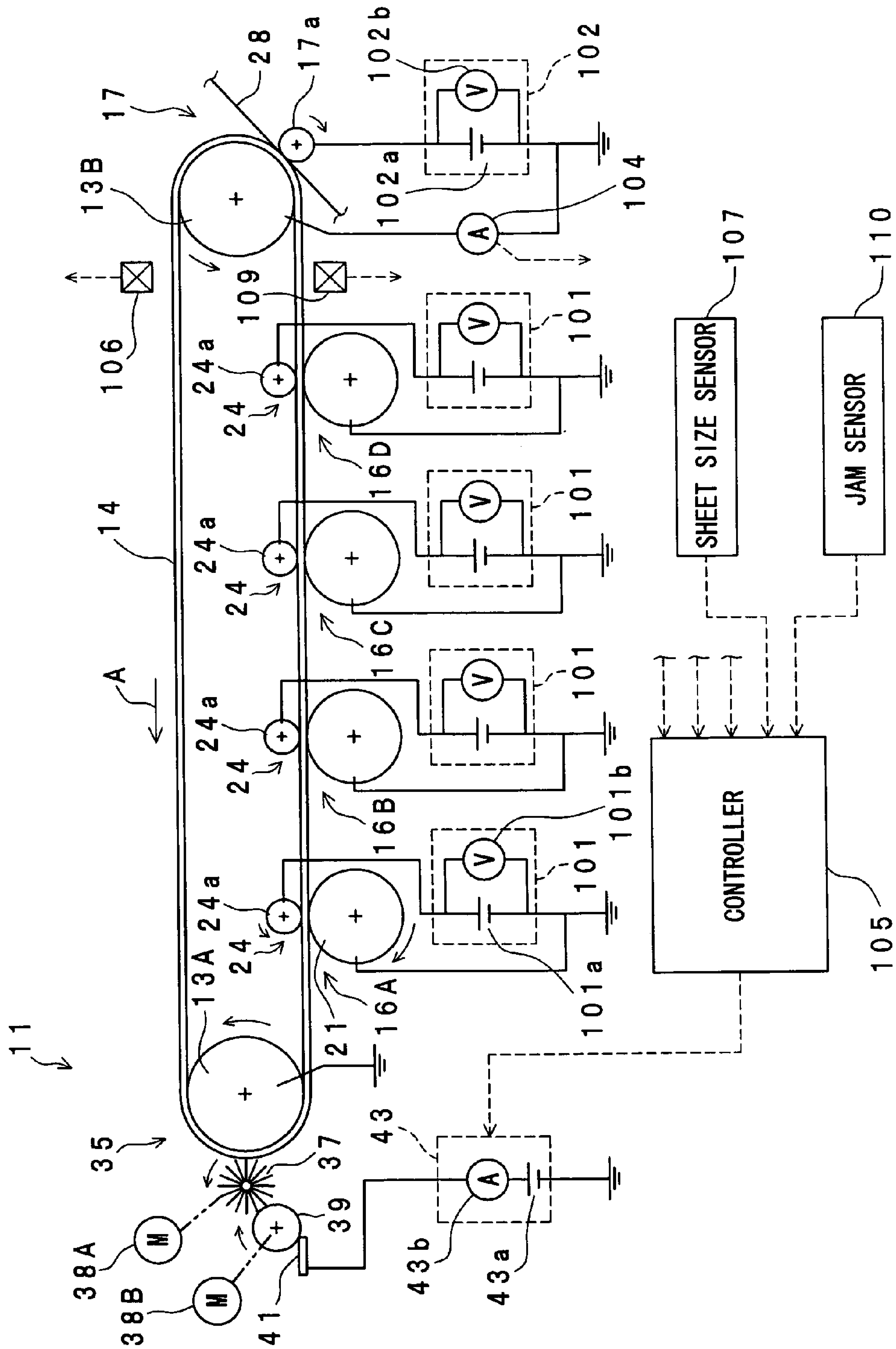

START
S24-1
IMAGE FORMATION OF NEW JOB ?
NO
YES
S24-2
SETTING ROTATIONAL SPEED R TO INITIAL VALUE
S24-3
MEASURING SECONDARY TRANSFER CURRENT It2
S24-4
It2≧It2th ?
NO
YES
S24-5
INCREASING ROTATIONAL SPEED R BY ΔR1
S24-6
MEASURING HUMIDITY H
S24-7
H≧Hth ?
NO
YES
S24-8
INCREASING ROTATIONAL SPEED R BY ΔR2
B1
B2

Fig.24B

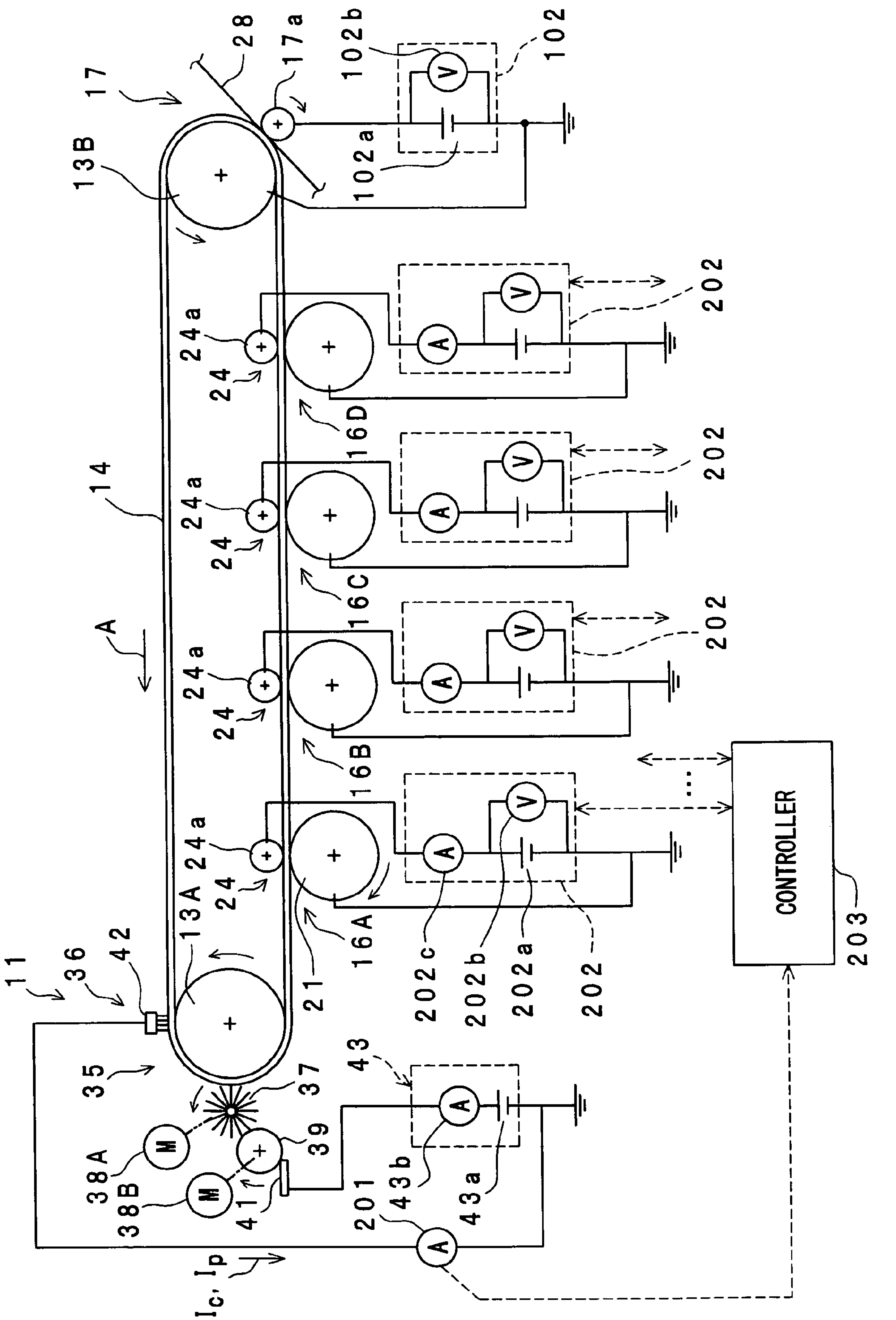

B1
B2
S24-9
READING DETECTION VALUE OF SHEET SIZE SENSOR 107
S24-10
SHEET SIZE IS EQUAL TO OR SMALLER THAN A4 SIZE ?
NO
YES
S24-11
INCREASING ROTATIONAL SPEED R BY ΔR3
S24-12
READING OUTPUT OF ATDC SENSOR 109
S24-13
D≧Dth ?
NO
YES
S24-14
INCREASING ROTATIONAL SPEED R BY ΔR4
S24-15
FIRST JOB AFTER JAMMING DETECTION ?
NO
YES
S24-16
INCREASING ROTATIONAL SPEED R BY ΔR5
RETURN



11
13A
13B
14
16A
16B
16C
16D
17
17a
21
24
24a
28
35
37
38A
38B
39
41
43
43a
43b
A
101
101a
101b
102
102a
102b
104
105
106
107
109
110
SHEET SIZE SENSOR
JAM SENSOR
CONTROLLER

Fig. 25

Fig. 26



CONTROLLER
11
13A
13B
14
16A
16B
16C
16D
17
17a
21
24
24a
28
35
36
37
38A
38B
39
41
42
43
43a
43b
102
102a
102b
201
202
202a
202b
202c
203
A
I_c, I_p

Fig.27

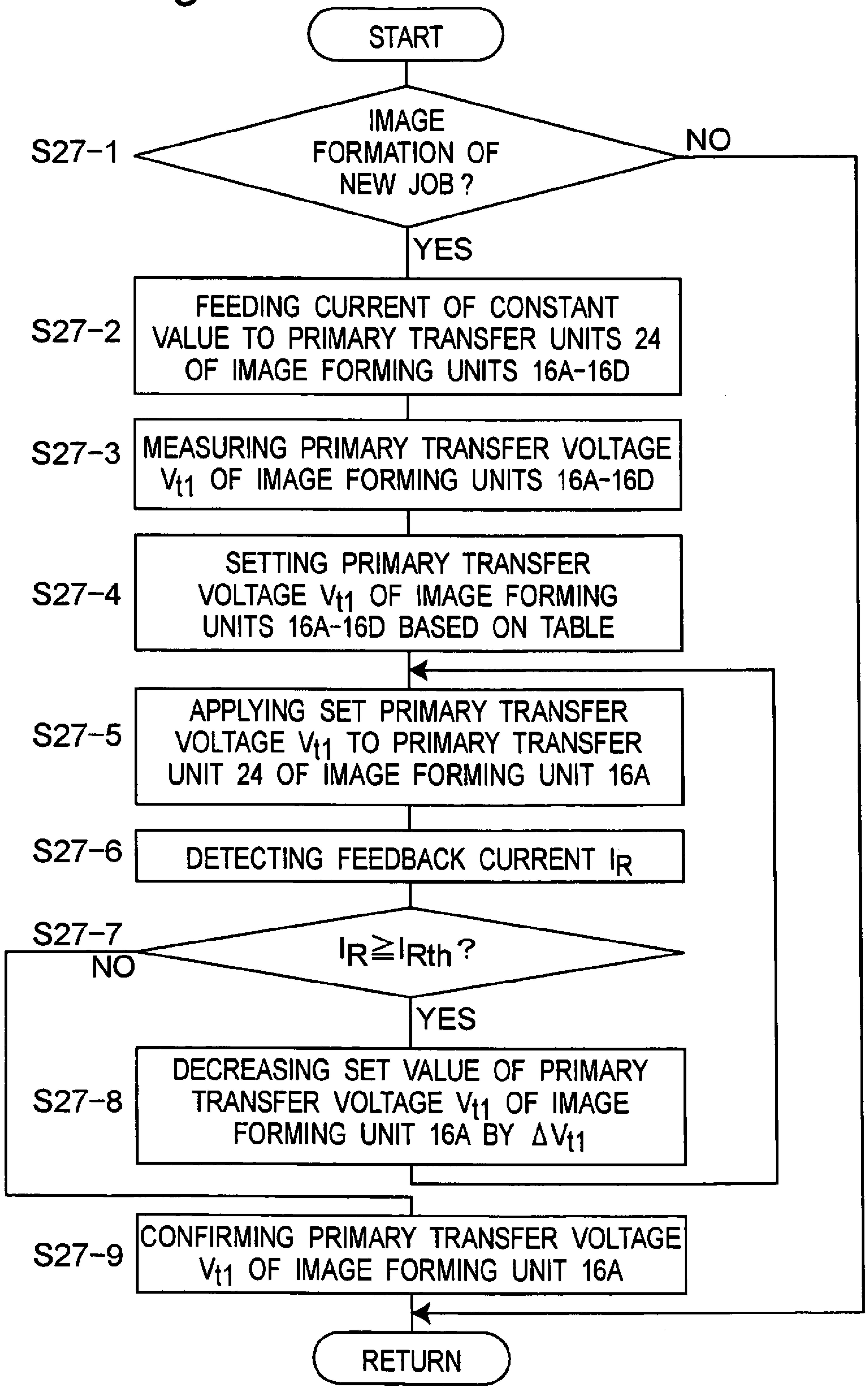

START
S27-1
IMAGE FORMATION OF NEW JOB ?
NO
YES
S27-2
FEEDING CURRENT OF CONSTANT VALUE TO PRIMARY TRANSFER UNITS 24 OF IMAGE FORMING UNITS 16A-16D
S27-3
MEASURING PRIMARY TRANSFER VOLTAGE V_{t1} OF IMAGE FORMING UNITS 16A-16D
S27-4
SETTING PRIMARY TRANSFER VOLTAGE V_{t1} OF IMAGE FORMING UNITS 16A-16D BASED ON TABLE
S27-5
APPLYING SET PRIMARY TRANSFER VOLTAGE V_{t1} TO PRIMARY TRANSFER UNIT 24 OF IMAGE FORMING UNIT 16A
S27-6
DETECTING FEEDBACK CURRENT I_R
S27-7
$I_R \geqq I_{Rth}$?
NO
YES
S27-8
DECREASING SET VALUE OF PRIMARY TRANSFER VOLTAGE V_{t1} OF IMAGE FORMING UNIT 16A BY ΔV_{t1}
S27-9
CONFIRMING PRIMARY TRANSFER VOLTAGE V_{t1} OF IMAGE FORMING UNIT 16A
RETURN

Fig. 28

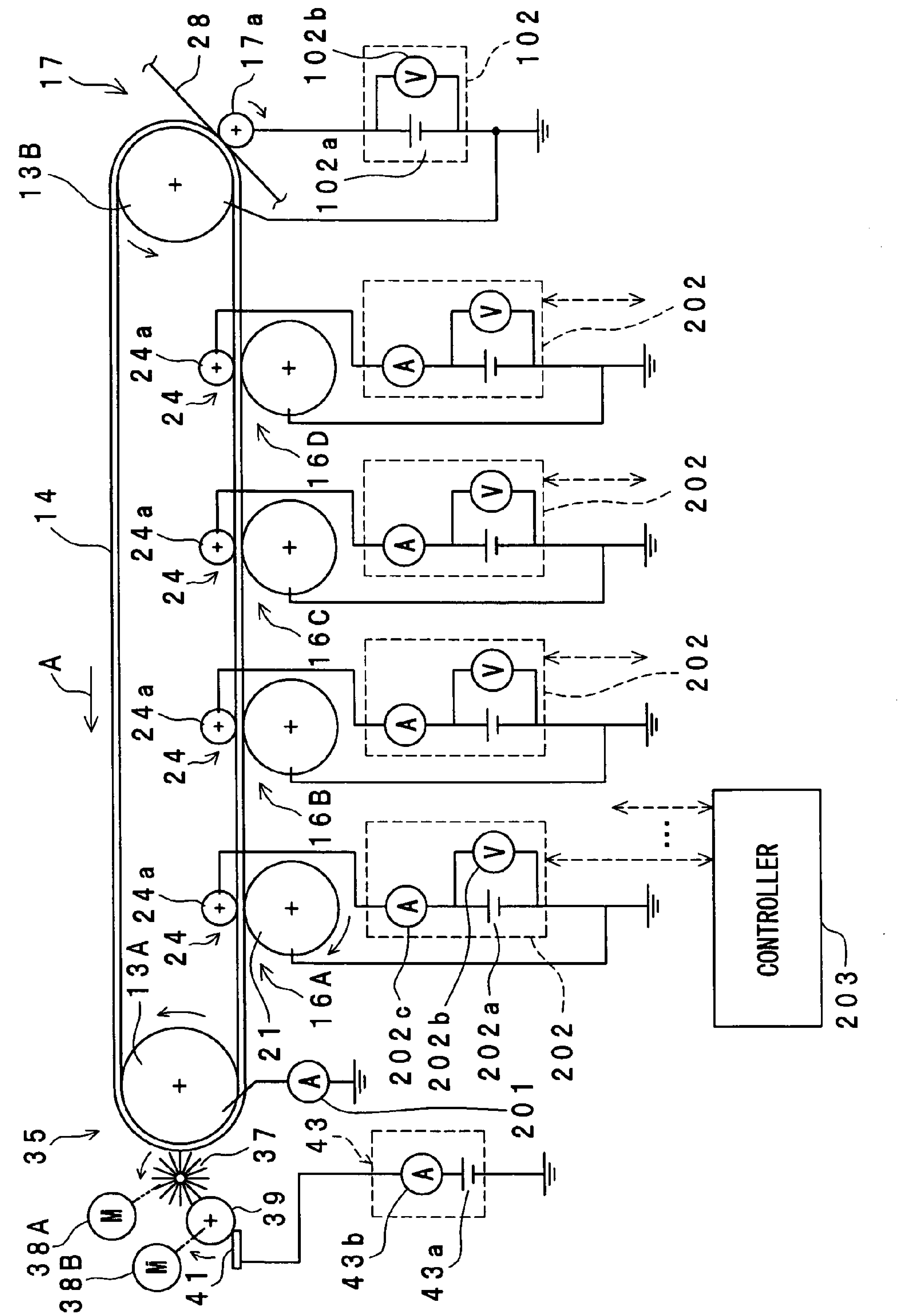

17
28
17a
102b
102
13B
102a
14
A
24a
24
16D
16C
16B
16A
13A
21
202
202c
202b
202a
201
35
37
43
38A
38B
39
41
43b
43a
CONTROLLER
203

Fig. 29

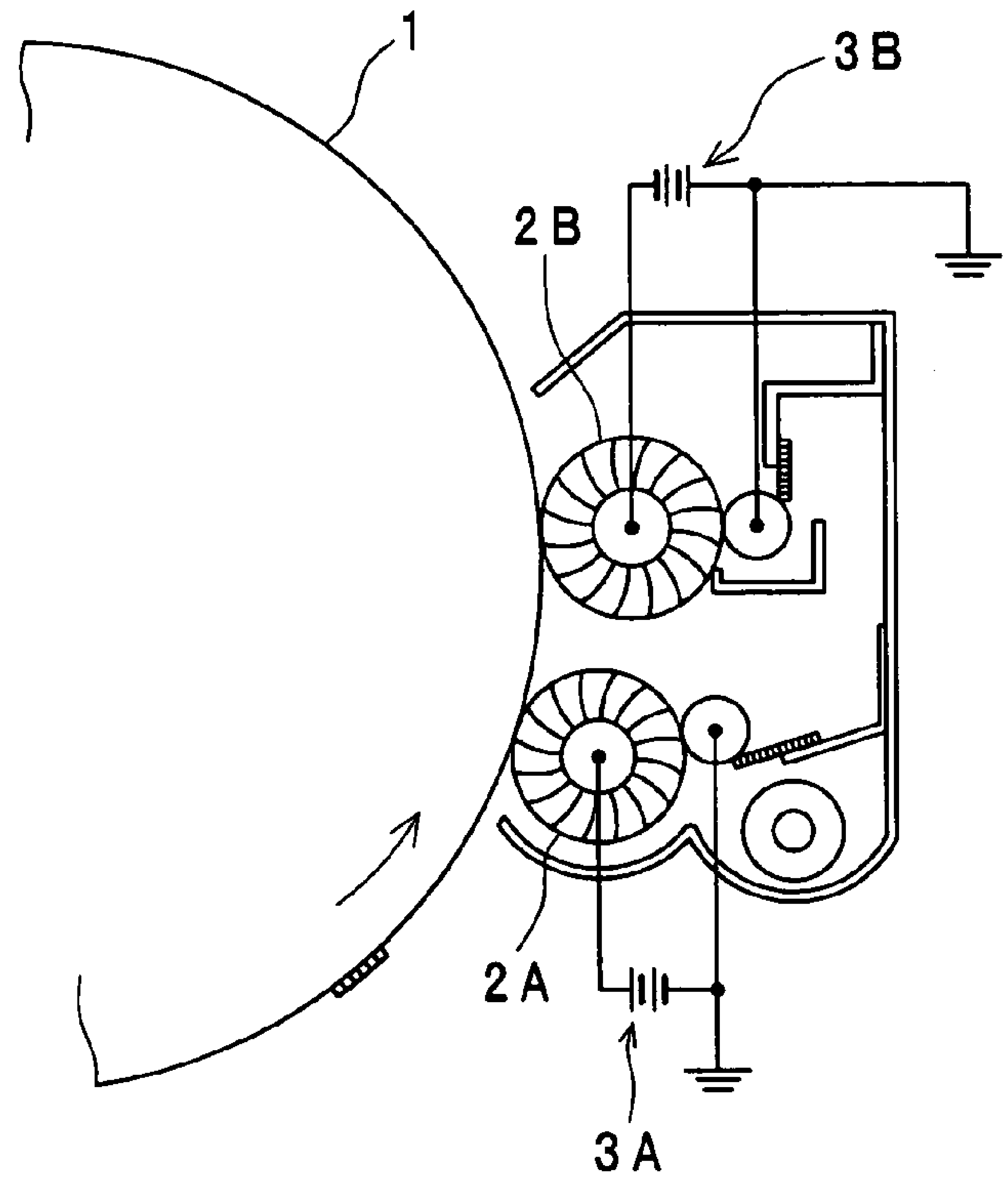
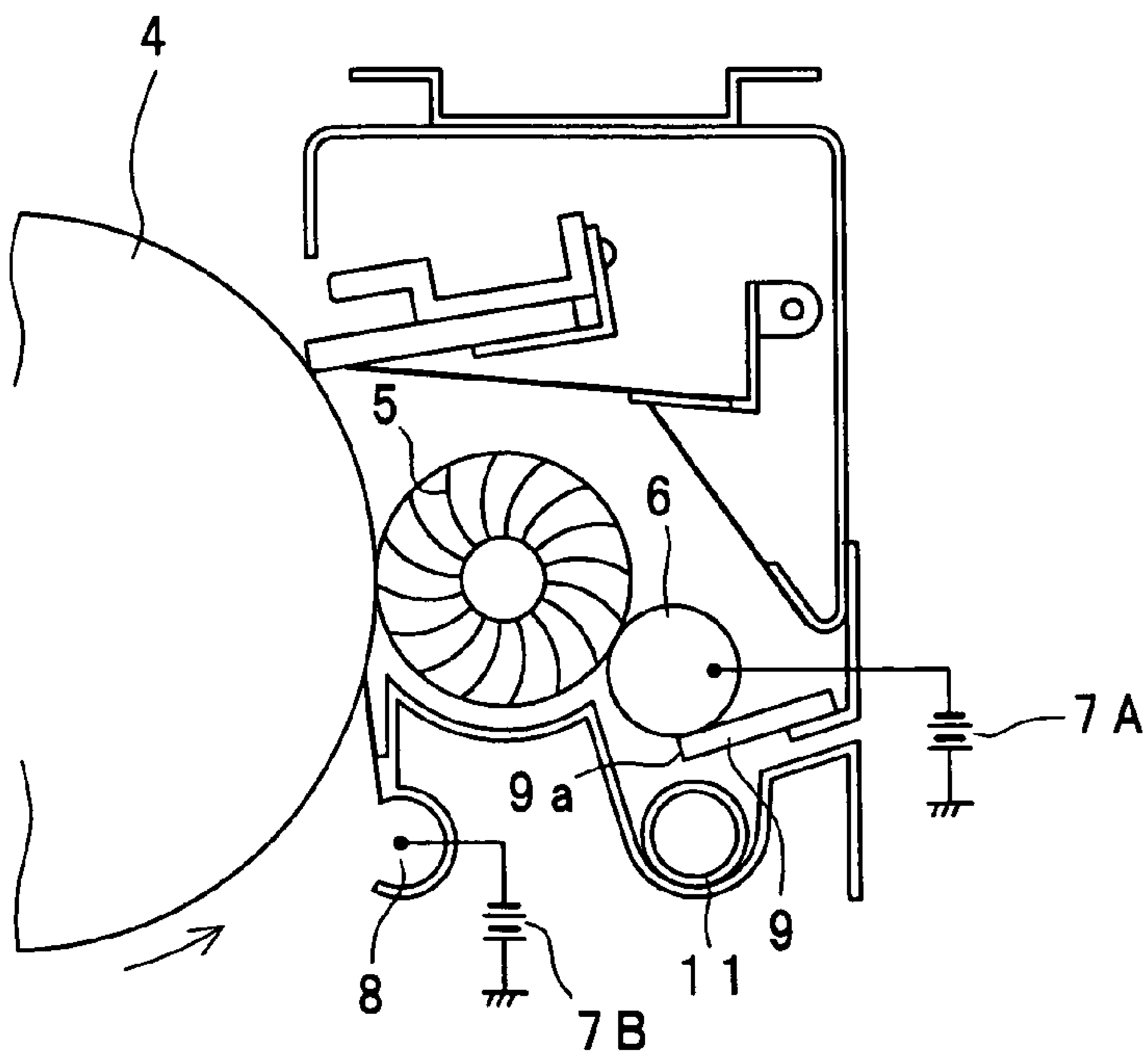


Fig. 30



CLEANING DEVICE FOR COLLECTING TONER ON A SURFACE OF AN IMAGE FORMING APPARATUS

RELATED APPLICATION

This application is based on applications Nos. 2003-85261, 2004-53834 and 2004-54334 filed in Japan, the contents to which is hereby incorporated by reference

BACKGROUND OF THE INVENTION

The present invention relates to a cleaning device and an image forming apparatus. More specifically, the present invention is preferably applied to cleaning devices provided in image forming apparatuses such as laser printers, copying machines, facsimile devices and multi-function machines of these apparatuses.

An image forming apparatus is provided with a cleaning device for collecting toner remaining on the surface of a photoconductor (e.g., photoconductor drum or photoconductor belt) or an intermediate transfer member (e.g., intermediate transfer belt or intermediate transfer drum) as image bearing bodies after transfer of a toner image. The toner remaining on the surface of the image bearing bodies after transfer is partially charged to a reverse polarity, thus being nonuniform in electric charge distribution. In order to effectively collect such residual toner, various cleaning devices have been proposed .

With reference to FIG. **29**, a cleaning device disclosed in Japanese utility model application laid-open publication No. H04-112274 is provided with a pair of fur brushes **2**A and **2**B disposed so as to be contact with the surface of a photoconductor **1**. Bias voltages with polarities opposite to each other are applied to each of the fur brushes **2**A, **2**B by individual power supplies **3**A, **3**B. The residual toner with a normal charge polarity (negative polarity) is collected by the fur brush **2**A to which a positive-polarity voltage is applied by the power supply source **3**A. The residual toner with a reverse polarity (positive polarity) is collected by the fur brush **2**B to which a negative-polarity voltage is applied by the power supply **3**B.

With reference to FIG. **30**, a cleaning device disclosed in Japanese patent application laid-open publication No. H08-50437 is provided with one fur brush **5** disposed so as to be contact with the surface of a photoconductor **4**. Bias voltage with a polarity (negative polarity) reverse to a normal charge polarity (positive polarity) of the residual toner is applied to the fur brush **5** via a collection roller **6** having conductivity by a power supply **7**A. Upstream from the fur brush **5** in the rotating direction of the photoconductor **4**, disposed is a charger **8** connected to a power supply **7**B. Before being collected by the fur brush **5**, the residual toner is charged or discharged by the charger **8**, and their charge polarity is unified. A similar cleaning device is also disclosed in Japanese Patent No. 2954812.

However, the conventional cleaning device requires a plurality of power supplies. For details, in the case of the cleaning device in FIG. **29**, two fur brushes **2**A, **2**B each require one power supply and so the total two power supplies **3**A, **3**B are necessary. Similarly, in the cleaning device in FIG. **30**, the fur brush **5** and the charger **8** each require one power supply and so the total two power supplies **7**A, **7**B are necessary. This increases size of the cleaning device and costs.

A charge amount of toner remaining on the surface of the image bearing body varies depending on various conditions such as a current flowing to a transfer portion. As in the case of the cleaning device in FIG. **30**, if the charger **8** for the discharging purpose is provided before the fur brush **5** as a cleaning member, the charge polarity and the charge amount of the toner having reached the fur brush **5** can be unified. However, since two power supplies are necessary as described before, the cleaning device grows in size. In the case of the cleaning device without a mechanism for discharge such as the charger **8**, a voltage to be applied to the cleaning member needs to be set high for securely collecting toner particles different in charge polarity and charge amount. However, this imposes the following problems. First, an excessive cleaning current flowing to an image bearing body charges the image bearing body and this would cause image failures. Moreover, the excessive cleaning current causes the image bearing body to have a shorter life. Further, if the charge amount of the toner is small, the toner is charged with a polarity reverse to a normal charge polarity due to the excessive cleaning current, which degrades a cleaning capability. Similarly, the amount of the toner remaining on the surface of the image bearing body varies depending on various conditions.

A primary transfer device in an image forming apparatus of intermediate transfer method, which is generally provided with a constant-voltage power supply, transfers a toner image on a photoconductor to an intermediate transfer member by applying a constant voltage with a polarity reverse to a normal charge polarity of the toner image. Accordingly, if a resistance of the intermediate transfer member is decreased by duration, or if a humidity inside the image forming apparatus is high, an excessive current generated in a primary transfer device could flow into the cleaning device via the intermediate transfer member. The excessive current generated in the primary transfer device damages the intermediate transfer member and causes the intermediate transfer member to have a shorter life.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a small-size and low-cost cleaning device capable of effectively removing residual toner on the surfaces of image bearing bodies. Another object of the present invention is to enable the cleaning device to maintain an appropriate cleaning capability even if the charge amount of residual toner or the amount of the residual toner has changed. Still another object of the present invention to prevent an excessive current from flowing from a primary transfer device to an intermediate transfer member.

In a first aspect of the present invention, there is provided a cleaning device for collecting toner on a surface of an image bearing body. According to this aspect of the invention, a rotary member has electrical conductivity and may be rotatively driven while being in contact with the surface of the image bearing body. Also included may be a conductive member which makes contact with the image bearing body on an upstream side of the rotary member in a feed direction of the image bearing body. A d.c. power supply can be connected to either the rotary member or the conductive member, where the one not connected to the d.c. power supply is grounded. Such an arrangement generates a d.c. current that flows via the image bearing body between the rotary member and the conductive member, whereby a first electric field in such a direction as to exert a force for adsorbing the toner of a normal charging polarity to the rotary member is generated between the rotary member and the image bearing body while a second electric field in a direction reverse to the first electric field is generated between the conductive member and the image bearing body.

In the cleaning device of the first aspect, toner of the normal charging polarity on the image bearing body surface is electrostatically adsorbed to the rotary member, and thereby collected, by the first electric field generated between the rotary member and the image bearing body. Also, since a second electric field reverse in direction to the first electric field is generated between the conductive member and the image bearing body, the conductive member serves as a charge elimination member so that the toner charged to a reversed polarity on the image bearing body surface becomes the normal charging polarity while passing through the conductive member. Thus, toner that has been uniformized in charging polarity to the normal charging polarity reaches the rotary member, allowing the collection of the toner to be efficiently achieved.

One of the rotary member and the conductive member is connected to the d.c. power supply, while the other is grounded, and the one-in-number d.c. power supply only is provided as the power supply for use of charge impartment or electric field generation. Thus, a downsizing of the apparatus and a reduction in cost become achievable. The rotary member may be connected to the d.c. power supply while the conductive member is grounded, alternatively, the conductive member may be connected to the d.c. power supply while the rotary member is grounded.

The image bearing body may be a photoconductor including a photoconductor drum and a photoconductor belt, and may be an intermediate transfer member including an intermediate transfer belt and an intermediate transfer drum.

The d.c. power supply is, for example, a regulated or constant-current d.c. power supply. Using the constant-current d.c. power supply as the power supply for use of electric field generation makes it possible to provide a certain amount of current flow even if the resistance has increased due to adhesion of the toner to the rotary member or the conductive member or due to the endurance changes of the image bearing body or the like. Thus, even with increased resistance, the strength of the electric field generated at the rotary member or the conductive member can be maintained, preventing any deterioration of the collection efficiency.

The d.c. power supply may be connected to the rotary member or the conductive member either indirectly or directly. For example, in the case where the rotary member is a fur brush, the d.c. power supply may be indirectly connected to it via a flicker or via a collection roller and scraper. Also, the d.c. power supply may be connected directly to the rotating shaft of the fur brush.

The rotary member may be one which has electrical conductivity and which rotates in a direction reverse to the conveyance direction of the image bearing body (feed direction in the case of a photoconductor belt or an intermediate transfer belt, the rotational direction in the case of a photoconductor drum or an intermediate transfer drum), and which is capable of at least electrostatically adsorbing and collecting the residual toner on the image bearing body surface. For example, the rotary member is a fur brush, a conductive elastic roller, or a metallic roller.

The conductive member may be one which has electrical conductivity and which makes uniform contact with the image bearing body surface, and which is small in frictional resistance with the surface of the image bearing body. For example, a conductive brush, a conductive film, conductive rubber, or a fur brush may be used as the conductive member.

The current fed from the d.c. power supply flows between the rotary member and the conductive member via the image bearing body. Therefore, when the image bearing body is an intermediate transfer belt stretched on a plurality of stretching rollers, the stretching roller opposite to the rotary member with the intermediate transfer belt interposed therebetween does not need to be grounded. This allows the stretching roller to be electrically floating state. Accordingly, even when the image forming apparatus is downsized so that the cleaning device is placed in proximity to the primary transfer section or the secondary transfer section, inflow of the transfer current from these transfer sections into the cleaning device can be prevented, thus allowing transfer failures due to inflow of the transfer current as well as image failures due to the inflow to be prevented.

Also, when the image bearing body is an intermediate transfer member, it is preferable that the distance between the rotary member and the conductive member is shorter than the distance between the rotary member and the primary transfer section or the secondary transfer section, whichever is closest to the rotary member, in order to further ensure the prevention of the inflow of the transfer current from the primary transfer section or the secondary transfer section. That is, preferably, the conductive member is placed so as to be spaced from the rotary member and the distance in the conveyance direction of the intermediate transfer member from the contact position of the rotary member with the intermediate transfer member to the contact position of the conductive member with the intermediate transfer member is shorter than the distance in the conveyance direction of the intermediate transfer member from the contact position of the rotary member with the intermediate transfer member to the both nip portions between the intermediate transfer member and the primary and secondary transfer sections.

Preferably, the direct current I_C (μA) flows between the rotary member and the conductive member via the image bearing body. The output voltage V_c (V) of the d.c. power supply, and the distance L_1 (mm) from the contact position of the rotary member with the image bearing body to the contact position of the conductive member with the image bearing body in the feed direction of the image bearing body satisfy the relationship of the following equation (1):

$$\frac{V_C - 312}{6200} < L_1 < \alpha \cdot \log_e I_c + \beta \quad (1)$$

The factors α and β are defined by the following equations (2) and (3):

$$\alpha = -1.80(\log_{10}\rho_S) + 11.39 \quad (2)$$

$$\beta = 1.98(\log_{10}\rho_S) + 15.39 \quad (3)$$

The right side of equation (1) defines a condition under which there occurs no cleaning failure due to an excessive increase in the surface voltage V_s of the rotary member. This condition was obtained by experiments. The left side of equation (1) defines a condition under which gap discharge does not occur between the rotary member and the conductive member. This condition was obtained by Paschen's law. If the direct current I_C flowing between the rotary member and the conductive member via the image bearing body, the surface voltage V_s of the rotary member, and the distance L_1 between the rotary member and the conductive member satisfy the relationship of equation (1), then successful cleaning performance can be obtained.

Preferably, the factor a is between or equal to −10.2 and −3.01, and the factor β is between or equal to 31.23 and 39.15.

The cleaning device may further include a second conductive member which makes contact with the image bearing body on an upstream side of the conductive member in the conveyance direction of the image bearing body. Preferably, the second conductive members is grounded. This second conductive member makes it possible to prevent powder smoke of the toner from scattering from the cleaning device to adhere to the image bearing body. The second conductive member functions also as a charge elimination member.

The cleaning device may also include a third conductive member which makes contact with the image bearing body on a downstream side of the rotary member in the conveyance direction of the image bearing body. Preferably, the third conductive member is connected to the d.c. power supply. This third conductive member prevents powder smoke of the toner derived from scattering out of the cleaning device. The third conductive member has a function of uniformizing the charging polarity of the toner on the image bearing body that has passed through the rotary member.

In a second aspect of the present invention, there is provided an image forming apparatus which has an image bearing body for carrying a toner image on a surface thereof. Also included may be a transfer section for transferring the toner image on the image bearing body surface onto a transfer-destination member by electric power fed from a first power supply. The apparatus may also include a current sensor for detecting a current flowing through the transfer section and a rotary member which is rotatably placed on a downstream side of the transfer section in a feed direction of the image bearing body so as to make contact with the image bearing body surface. Preferably, the rotary member is electrically conductive. A motor for rotating the rotary member may also be provided. A second power supply for supplying electric power to the rotary member, whereby toner remaining on the image bearing body surface after transfer is electrostatically adsorbed to the rotary member may also be provided. A controller for controlling either the output of the second power supply or the rotational speed of the motor based on a current value detected by the current sensor.

More specifically, the larger the current value detected by the current sensor is, the more the controller increases the output of the second power supply. Also, the larger the current value detected by the current sensor is, the more the controller increases the rotational speed of the motor in addition to or instead of the adjustment of the output of the second power supply.

The image forming apparatus may also include an environment sensor for detecting an environmental condition. In this case, the controller further controls at least one of the output of the first power supply and the rotational speed of the motor based on an environmental condition detected by the environment sensor. The environment sensor can detect temperature or humidity as the environmental condition, as an example.

The image forming apparatus may further comprise a size sensor for detecting size of the transfer-destination member. In this case, the controller controls at least one of the output of the first power supply and the rotational speed of the motor based on a size of the transfer-destination member detected by the size sensor.

The image forming apparatus may further comprise a toner quantity detection sensor for detecting the quantity of toner on the image bearing body surface. In this case, the controller controls at least one of the output of the first power supply and the rotational speed of the motor based on the detected toner quantity. The image forming apparatus may further comprise a jamming detection sensor for detecting occurrence of a jamming of the transfer-destination medium. The controller may control at least one of the output of the first power supply and the rotational speed of the motor based on a detection result of the jamming detection sensor. The controller may at least one of the output of the first power supply and the rotational speed of the motor by further taking into consideration other conditions such as the type of the transfer-destination member.

When the image bearing body is an intermediate transfer belt, the transfer section includes a secondary transfer roller that forms a nip portion, through which the transfer-destination member passes, against the surface of the intermediate transfer belt, and a stretching roller which is opposite to this secondary transfer roller and which contacts with the rear surface of the intermediate transfer belt, wherein the current sensor detects a current flowing through this stretching roller.

In a third aspect of the present invention, the image forming apparatus may include an image bearing body for carrying a toner image on a surface thereof, and an intermediate transfer member which contacts with the image bearing body. Also included may be a primary transfer section for transferring the toner image on the image bearing body surface to the intermediate transfer member by electric power being fed from a first power supply. A secondary transfer section may be placed on a downstream side of the primary transfer section in a feed direction of the intermediate transfer member and may transfer the toner image on the intermediate transfer member to a transfer-destination member. A rotary member may be placed on a downstream side of the secondary transfer section in the feed direction of the intermediate transfer member and may be rotatively driven while making contact with a surface of the intermediate transfer member. The rotary member may be electrically conductive. A second power supply for supplying electric power to the rotary member may be provided, whereby toner remaining on the intermediate transfer member even after the toner image has been transferred to the transfer-destination member is electrostatically adsorbed to the rotary member. A grounded conductive member which makes contact with the intermediate transfer member and which is electrically connected to the second power supply via the rotary member and the intermediate transfer member may also be included. A current sensor may detect a current flowing through the conductive member. A controller for controlling an output of the first power supply based on a current value detected by the current sensor be also be provided.

For instance, the conductive member is placed on the upstream side of the rotary member in the conveyance direction of the intermediate transfer member. When the intermediate transfer member is an intermediate transfer belt stretched on a plurality of stretching rollers, the conductive member may be one of the plurality of stretching rollers which is opposite to the rotary member.

More specifically, the controller adjusts an output voltage of the first power supply so that the current value detected by the current sensor does not exceed a predetermined threshold value.

A current flowing the conductive member electrically connected to the second power supply via the rotary member and the conductive member through is detected by the current sensor. When an excessive current flows through the intermediate transfer member in the primary transfer section for such reasons as resistance decreases of the intermediate transfer member due to endurance or humidity increases within the image forming apparatus, this current flows into the conductive member via the intermediate transfer member. As a result, the current value detected by the current sensor increases. That is, the current value detected by the current sensor serves as an index for indicating whether or not an excessive current is flowing through the intermediate transfer member in the primary transfer section. Accordingly, by the controller controlling the output of the first power supply based on the current detected by the current sensor, flow of an excessive current through the intermediate transfer member can be prevented. As a consequence, there is no possibility that the intermediate transfer member may be damaged by the flow of an excessive current, and thus the serve life of the intermediate transfer member can be prolonged.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the invention will become apparent from the following description taken in conjunction with preferred embodiments of the invention with reference to the accompanying drawings, in which:

FIG. **1** is a schematic view showing a laser printer having a cleaning device according to a first embodiment of the present invention;

FIG. **2** is a schematic view showing the cleaning device according to the first embodiment of the present invention;

FIG. **3** is a plane view showing the cleaning device according to the first embodiment of the present invention;

FIG. **4** is a schematic circuitry view showing a constant-current d.c. power supply;

FIG. **5**A is a schematic view showing a cleaning electric field generated in a collection section;

FIG. **5**B is a schematic view showing an electric field generated in a discharge section;

FIG. **6** is a schematic view showing a cleaning device according to a second embodiment of the present invention;

FIG. **7** is a schematic view showing a cleaning device according to a third embodiment of the present invention;

FIG. **8** is a schematic view showing a cleaning device according to a fourth embodiment of the present invention;

FIG. **9** is a schematic view showing a cleaning device according to a fifth embodiment of the present invention;

FIG. **10** is a schematic view showing a cleaning device according to a sixth embodiment of the present invention;

FIG. **11** is a schematic view showing a cleaning device according to a seventh embodiment of the present invention;

FIG. **12** is a schematic view showing a cleaning device according to an eighth embodiment of the present invention;

FIG. **13** is a schematic view showing a cleaning device of a modified example of the eighth embodiment of the present invention;

FIG. **14** is a schematic view showing a cleaning device of a modified example of the eighth embodiment of the present invention;

FIG. **15** is a graph view showing a relation between distance L_1 and voltage when the surface resistance of the transfer belt is 1×10^{10} Ω/□;

FIG. **16** is a graph view showing a relation between distance L_1 and voltage when the surface resistance of the transfer belt is 1×10^{11} Ω/□;

FIG. **17** is a graph view showing a relation between the surface resistance and the voltage of the transfer belt;

FIG. **18** is a graph view showing a relation between applied current and resistance L_1 when the output voltage is 5 kV;

FIG. **19** is a graph view showing a change of a coefficient a with respect to a logarithmic value of the surface resistance of the transfer belt;

FIG. **20** is a graph view showing a change of a coefficient β with respect to a logarithmic value of the surface resistance of the transfer belt;

FIG. **21** is a graph view showing a result of substituting various surface resistance values of the various transfer belt and cleaning current values into a conditional expression of the present invention;

FIG. **22** is a schematic view showing a cleaning device according to a ninth embodiment of the present invention;

FIG. **23**A is a flowchart explaining the operation of the cleaning device according to the ninth embodiment of the present invention;

FIG. **23**B is a flowchart explaining the operation of the cleaning device according to the ninth embodiment of the present invention;

FIG. **24**A is a flowchart explaining the operation of a cleaning device of a modified example of the ninth embodiment of the present invention;

FIG. **24**B is a flowchart for explaining the operation of a cleaning device of a modified example of the ninth embodiment of the present invention;

FIG. **25** is a schematic view showing a cleaning device of a modified example of the ninth embodiment of the present invention;

FIG. **26** is a schematic view showing an image forming apparatus according to a tenth embodiment of the present invention;

FIG. **27** is a flowchart explaining the operation of the image forming apparatus according to the tenth embodiment of the present invention;

FIG. **28** is a schematic view showing an image forming apparatus of a modified example of the tenth embodiment of the present invention;

FIG. **29** is a schematic view showing one example of a conventional cleaning device; and

FIG. **30** is a schematic view showing another example of a conventional cleaning device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiment of the present invention will now be described in detail with reference to the accompanying drawings.

(First Embodiment)

FIG. **1** shows a laser printer **12** of tandem process method exemplifying an image forming apparatus having a secondary cleaning device **11** (hereinbelow referred to as a cleaning device **11**) according to a first embodiment-of the present invention. It is to be noted that in the present embodiment, a normal charge polarity of toner is negative.

An intermediate transfer belt **14** (hereinbelow referred to as a transfer belt **14**) stretched between a pair of stretching rollers **13**A and **13**B is forwarded to a direction shown with an arrow A by rotation of the stretching rollers **13**A, **13**B. Around the transfer belt **14**, there are disposed first to fourth image forming units **16**A–**16**D, a secondary transfer device **17**, and a cleaning device **11**.

The image forming units **16**A–**16**D each transfer images in yellow (Y), magenta (M), cyan (C) and black (Br) to the transfer belt **14**. The image forming units **16**A–**16**D have the same structure, in which a charging device **22**, a developing device **23**, a primary transfer device **24**, and a primary cleaning device **25** are provided around a photoconductor drum **21**. The surface of the photoconductor drum **21** that is evenly charged by the charging device **22** is exposed to a laser beam radiated from a laser device **26** to form an electrostatic latent image. The electrostatic latent image is developed into a toner image with toner supplied by the developing device **23**. The toner image is transferred onto the surface of the transfer belt **14** with a positive voltage that is applied to the back surface side of the transfer belt **14** by the primary transfer device **24**. Toner remaining on the surface of the photoconductor drum **21** after this primary transfer is collected by the primary cleaning device **25**.

Every time the transfer belt **14** passes through the image forming units **16**A–**16**D, toner images are transferred onto the transfer belt **14** in the state of being superposed on each other (it is to be noted that in the case of a monochrome image, a toner image is transferred onto the transfer belt **14** only by the image forming unit **16**D). The transferred toner image is transferred onto a record medium **28** such as a paper sheet that is transported from a sheet feed cassette **27** by the secondary transfer device **17**. More specifically, with a positive voltage applied to the back surface of the record medium **28**, the toner image is transferred from the transfer belt **14** to the record medium **28**. Toner **30** remaining on the transfer belt **14** after the transfer by the secondary transfer device **17** includes toner charged with a normal charge polarity (negative) as well as toner charged with a reverse polarity (positive). The recording medium **28** onto which the toner image is transferred is sent to a fixing device **31**, and then the toner image is fixed to the record medium **28** through pressurization and heating.

The cleaning device **11** is described with reference to FIG. **2** and FIG. **3**. The cleaning device **11** is provided with a collection section **35** for collecting the toner **30** and a discharging section **36** that is positioned upstream with respect to the collection section **35** in a transportation direction of the intermediate gear **14**. The discharging section **36** unifies the polarity of the toner **30** that is charged with a reverse polarity.

The collection section **35** has a fur brush (rotational member) **37** that comes into contact with the surface of the transfer belt **14**. The fur brush **37** is formed by implanting resinous hairs having a resistance of, for example, about 1×10^4 to 1×10^7 Ω/□ around a cored bar **37***a*. The fur brush **37** is driven to be rotated in a direction opposite to a forward direction of the transfer belt **14** by a motor **38**A. The fur brush **37** is in contact with a metallic collection roller **39** having conductivity. The collection roller **39** is driven to be rotated in a direction opposite to the fur brush **37** by a motor **38**B. Moreover, the collection roller **39** is in contact with a metallic scraper **41** that has conductivity so as to function as an electrical contact member. With reference to FIG. **3**, a width W1 of the fur brush **37** is larger than a maximum width W2 of the record medium **28** and is smaller than a width W3 of the transfer belt **14**. Therefore, regardless of the size of the record medium **28**, there are regions ΔW on the both side portions of the transfer belt **14**, in which the fur brush **37** and the transfer belt **14** face each other without the presence of the recording medium **28** interposed therebetween.

The discharging section **36** has a conductive brush (conductive member) **42** that is formed by implanting resinous hairs having resistance in a conductive metallic base portion. The power supply **43** is in contact with the surface of the transfer belt **14**.

The fur brush **37** of the collection section **35** is electrically connected to a regulated or constant-current d.c. power supply **43**. More particularly, one end of the scraper **41** is connected to the constant-current d.c. power supply **43**, thereby the fur brush **37** is indirectly connected to the constant-current d.c. power supply **43** via the scraper **41** and the collection roller **39**. The constant-current d.c. power supply **43** is connected to the fur brush **37** so as to generate a cleaning electric field with a polarity reverse to a normal charge polarity of the toner **30**. In this embodiment, the normal charge polarity of the toner **30** is negative as described above, and so a positive terminal of the constant-current d.c. power supply **43** is connected to the fur brush **37** via the scraper **41** and the collection roller **39**. The base portion **42** of the discharging section **36** is simply grounded without being connected to the power supply.

As shown in FIG. **4**, the constant-current d.c. power supply **43** includes a d.c. power supply **43***a* and a current sensing element **43***b* connected in series to the d.c. power supply **43***a*, and has a function of controlling the output voltage so as to maintain the current value constant.

As shown in a dot line in FIG. **2**, a cleaning current I_C flows from the constant-current d.c. power supply **43** through the scraper **41**, the collection roller **39**, the fur brush **37**, and the transfer belt **14** to the base portion **42**. With reference to FIG. **5**A, between the fur brush **37** and the transfer belt **14** in the collection section **35**, there is generated an electric field (cleaning electric field) E_1 with a polarity on the opposite side of a normal charge polarity of the toner **30**, i.e., the electric field directed from the fur brush **37** to the transfer belt **14**. As shown with an arrow F_E, the cleaning electric field E1 causes a force of electrostatically adsorbing the toner **30** with a normal charge polarity (negative) presented on the surface of the transfer belt **14** toward the fur brush **37**. The toner **30** is collected from the transfer belt **14** by being electrostatically adsorbed to the fur brush **37**. Due to an electric potential difference between the fur brush **37** and the collection roller **39**, the toner **30** adsorbed to the surface of the fur brush **37** is moved to the collection roller **39**, and is scraped off from the surface of the collection roller **39** by the scraper **41**.

Also with reference to FIG. **5**B, between a conductive brush **42** and the transfer belt **14** in the discharging section **36**, there is generated an electric field E_2 (electric field opposite to the cleaning electric field E_1) with a polarity on the same side of the normal charge polarity of the toner **30**. Due to the electric field E_2, the toner **30** charged with a polarity reverse to that on the surface of the transfer belt **14** become to have the normal charge polarity (negative) when they pass through the conductive brush **42**. Therefore, the toner **30** with a charge polarity that has been unified to be the normal charge polarity reaches the fur brush **37**, and the fur brush **37** allows the toner **30** to be effectively collected from the transfer belt **14**.

As described before, the electric fields E_1 and E_2 which are different in direction from each other are generated in the collection section **35** and the discharging section **36**. These electric fields E_1 and E_2 are generated by the cleaning current I_C that flows from the fur brush **37** of the collection section **35** connected to the constant-current d.c. power supply **43** to the conductive brush **42** of the discharging section **36** via the transfer belt **14**. Only the fur brush **37** of the collection section **35** is connected to the constant-current d.c. power supply **43** while the conductive brush **42** of the discharging section **36** is grounded. In other words, only a single constant-current d.c. power supply **43** functions as a power supply for giving charges or generating an electric field. This achieves downsizing of the device and reduction of costs.

The constant-current d.c. power supply **43** has a rated current of, for example, 10 to 100 μA, and a maximum voltage of, for example, about 0.3 to 4 kV. In order to generate an electric field with sufficient intensity in the collection section **35** and the discharging section **36**, a resistance of the transfer belt **14** should preferably be, for example, 1×10^{8} Ω/□ or more and 1×10^{12} Ω/□ or less. Materials such as polyimide, polycarbonate and polyphenylene sulfide can be used for the transfer belt **14**.

Moreover, as a power supply for generating an electric field, the constant-current d.c. power supply **43** is used. Consequently, even if a resistance is increased by adhesion of the toner **30** to the fur brush **37**, the collection roller **39**, or the conductive brush **42**, and by change in duration of the transfer belt **14** and the like, a constant amount of current flows. Therefore, even with increase in resistance, it is possible to maintain the field intensity of the collection section **35** and the discharging section **36**, resulting in prevention of deterioration of the collection efficiency.

Further, a current fed by the constant-current d.c. power supply **43** flows between the fur brush **37** of the collection section **35** and the conductive brush **42** of the discharging section **36** via the transfer belt **14**. This eliminates the need for grounding the stretching roller **13**A that faces the collection section **35** and the discharging section **36** with the transfer belt **14** interposed therebetween. For this reason, in the present embodiment, the stretching roller **13**A, which is a conductive roller, is maintained in an electrically floating state by supporting an axis thereof with a bearing made of an insulating resin. Therefore, even in the case of disposing the cleaning device **11** adjacent to the primary transfer device **24** and the secondary transfer device **17** for the sake of downsizing, it is possible to prevent a transfer current from the primary transfer or secondary device **24**, **27** from flowing into the stretching roller **13**A via the transfer belt **14**. This allows prevention of a transfer failure due to influx of the transfer current and an image failure attributed to the transfer failure.

The conductive brush **42** of the discharging section **36** needs to be disposed at a position not in contact with the fur brush **37** of the collection section **35**. For example, a distance L_1 from a nip portion of the fur brush **37** against the transfer belt **14** to a contact position of the conductive brush **42** to the transfer belt **14** in a forward direction of the transfer belt **14** should be set at ½ or more of a diameter of the fur brush **37**. A preferable setting range of the distance L_1 will be described later in detail.

In order to ensure prevention of influx of a transfer current from the primary transfer device **24** and the secondary transfer device **17**, the distance L_1 between the fur brush **37** and the conductive brush **42** should preferably be smaller than a distance between the fur brush **37** and the closest primary transfer device **24** or the secondary transfer device **17**. In this embodiment, the primary transfer device **24** of the image forming unit **16**A is closest to the fur brush **37**. Therefore, the distance L_1 is smaller than the forward-direction distance L**2** from the nip portion of the fur brush **37** against the transfer belt **14** to a nip portion of the primary transfer device **24** of the image forming unit **16**A.

(Second Embodiment)

In a second embodiment of the present invention shown in FIG. **6**, instead of the fur brush **37** (see FIG. **2**), the collection section **35** is provided with a conductive elastic roller **45** having a conductive rubber layer on the perimeter of a core metal. Other structure and operation of the second embodiment are similar to those of the first embodiment.

(Third Embodiment)

In a third embodiment of the present invention shown in FIG. **7**, the fur brush **37** of the collection section **35** has conductivity and is connected to the constant-current d.c. power supply **43** via a flicker **46** that functions also as a contact member. The toner **30** collected by the fur brush **37** is scraped off by the flicker **46**. Moreover, instead of the conductive brush **42** (see FIG. **2**), the discharging section **36** is provided with a conductive film **47**. The distal end side of the conductive film **47** is in contact with the transfer belt **14**, while its proximal end side is supported by a holder having conductivity. The conductive film **47** is grounded via the holder. Cleaning current I_C flows from the constant-current d.c. power supply **43** through the flicker **46**, the fur brush **37**, and the transfer belt **14** to the conductive film **47**. Other structure and operation of the third embodiment are similar to those of the first embodiment.

(Fourth Embodiment)

In a fourth embodiment of the present invention shown in FIG. **8**, the conductive brush **42** of the discharging section **36** is connected to the constant-current d.c. power supply **43**, and the fur brush **37** of the collection section **35** is grounded via the flicker **46**. A negative terminal of the constant-current d.c. power supply **43** is connected to the conductive brush **42**. By the cleaning current I_C flowing from the constant-current d.c. power supply **43** through the conductive brush **42** and the transfer belt **14** to the fur brush **37**, a cleaning electric field E_1 with a polarity reverse to a normal charge polarity of the toner **30** is generated in the fur brush **37**, whereas an electric field E_2 with a polarity reverse to that of the cleaning electric field is generated in the conductive brush **42**. Other structure and operation of the fourth embodiment are similar to those of the first embodiment.

(Fifth Embodiment)

In a fifth embodiment of the present invention shown in FIG. **9**, a conductive brush **37** of the collection section **35** is connected to the constant-current d.c. power supply **43** via the flicker **46**. Moreover, the discharging section **36** is provided with a fur brush **57** that is grounded via a flicker **56**. The fur brush **57** is driven to be rotated in a direction opposite to the forward direction of the transfer belt **14** by a motor **38**C. Other structure and operation of the fifth embodiment are similar to those of the first embodiment.

(Sixth Embodiment)

In a sixth embodiment of the present invention shown in FIG. **10**, the collection section **35** having the fur brush **37** connected to the constant-current d.c. power supply **43** via the flicker **46**, and the discharging section **36** having a grounded conductive film **47** are disposed on the side closer to the secondary transfer device **17** (upstream in a transportation direction of the transfer belt **14**) than in the first to fifth embodiments. Thus, the cleaning device of the present invention can be disposed in an arbitrary position along on the transfer belt **14** under a condition that the distance from the collection section **35** to the discharging section **36** (distance L_1) is smaller than the distance between the collection section **35** and the closest primary transfer device **9** or the secondary transfer device **17** (distance L_2).

(Seventh Embodiment)

In a seventh embodiment of the present invention shown in FIG. **7**, in addition to a cleaning device **11** with the same structure as the first embodiment, a cleaning blade **48** is provided downstream in a forward direction of the transfer belt **14**. The distal end of the cleaning blade **48** is in contact with the transfer belt **14**, and the toner **30** that has passed through the collection section **35** is removed from the surface of the transfer belt **14** by the cleaning blade **48**. Other structure and operation of the seventh embodiment are similar to those of the first embodiment.

(Eighth Embodiment)

In an eighth embodiment of the invention shown in FIG. **12**, with a spacing to the conductive film **47** of the discharging section **36**, another conductive film **61** is provided on the upstream side in the feed direction of the transfer belt **14**. This conductive film **61** is in contact with the transfer belt **14** on its distal end side, while supported on its proximal end side by a holder having conductivity. The conductive film **61** is grounded.

By the provision of the conductive film **61**, the interior of the cleaning device **11** is sealed, so that the possibility that powder smoke of the toner **30** generated by the fur brush **37** may diffuse outside the cleaning device **11** to re-adhere to the transfer belt **14** can be prevented. In order to securely seal the powder smoke of the toner **30**, the conductive film **61** preferably has enough flexibility and tightly contacts with the transfer belt **14**. Therefore, the conductive film **61** is preferably made of a material lower in hardness than the conductive film **47** of the discharging section **36** and smaller in thickness than conductive film **47**.

Since the conductive film **61** is grounded, part of the cleaning current I_C flows into the conductive film **61** from the constant-current d.c. power supply **43** via the flicker **46**, the fur brush **37**, and the transfer belt **14**. This current generates an electric field between the conductive film **61** and the transfer belt **14** so that the electric is directed in the same direction as the electric field E_2 between the conductive film **47** and the transfer belt **14** in the charge-eliminating section **36** (see FIG. **5**B). Therefore, the conductive film **61** preliminary uniformizes the charge of the toner **30** remaining on the transfer belt **14** before its reaching the charge-eliminating section **36**. Thus, this conductive film **61** allows the discharging performance to be improved as a whole of the cleaning device **11**. In addition, a resistor may be interposed between the conductive film **61** and the grounding portion in order to adjust the strength of the electric field generated between the conductive film **61** and the transfer belt **14**.

An insulative film may also be adopted instead of the conductive film **61**. This insulative film indeed does not have the static elimination function, but can seal the powder smoke of the toner **30** generated by the fur brush **37**.

Another conductive film **62** is provided with a spacing to the fur brush **37** of the collection section **35** in the feed direction of the transfer belt **14**. This conductive film **62** is in contact with the transfer belt at its distal end side **14**, while supported on its proximal end side by a holder having conductivity. The conductive film **62** is connected to the d.c. power supply **43** via a resistor **63**.

Like the conductive film **61** disposed on the upstream side of the discharging section **36**, the conductive film **62** prevents powder smoke of the toner **30** generated by the fur brush **37** from diffusing outside the cleaning device **11**.

Since the conductive film **62** is in contact with the transfer belt **14**, part of the cleaning current I_C derived from the constant-current d.c. power supply **43** flows into the transfer belt **14** via the conductive film **62**. By this current, an electric field of the same direction as the electric field E_2 generated between the conductive film **47** and the transfer belt **14** in the charge-eliminating section **36** (see FIG. **5**B) is generated between the conductive film **62** and the transfer belt **14**. Therefore, the conductive film **62** has a function of uniformizing the charge polarity of the toner **30** on the transfer belt **14** that has passed through the collection section **35** without being collected by the fur brush **37**.

Instead of the conductive film **61** upstream of the discharging section **36** in the feed direction of the transfer belt **14**, a conductive brush **65** may be provided as shown in FIG. **13**. The conductive brush **65** has no function of sealing the powder smoke of the toner **30**, but discharges static charge of the residual toner **30** on the transfer belt **14**. Likewise, the conductive film **62** on the downstream side of the collection section **35** in the feed direction of the transfer belt **14** may be replaced with a conductive brush. Further, as shown in FIG. **14**, the cleaning device **11** of FIG. **12** may be disposed at more upstream side of the transfer belt **14**. Furthermore, the cleaning device **11** may be provided with either one of the conductive films **61** and **62**.

As a result of experiments and analyses, the present inventors have found out that the cleaning devices **11** of the first to eighth embodiments exert proper cleaning performance when conditions defined by the following equation (4) are satisfied:

$$\frac{V_C - 312}{6200} < L_1 < \alpha \cdot \log_e I_c + \beta \tag{4}$$

In equation (4), I_C represents a cleaning current (μA) flowing between a rotary member (fur brush **37** or conductive roller **45**) of the collection section **35** and a conductive member (conductive brush **42**, conductive film **47**, or fur brush **57**) of the charge-eliminating section **36** via the transfer belt **14** as an image bearing body. Also, V_c represents an output voltage (V) of the constant-current d.c. power supply **43**. Further, L_1 represents a distance (mm) in the feed direction of the transfer belt **14** from the contact position of the rotary member with the transfer belt **14** to the contact position of the conductive member with the transfer belt **14**.

In equation (4), α and β are factors related to the surface resistance of the transfer belt **14**. The factors of the transfer belt **14** are defined by the following equations (5) and (6):

$$\alpha = -1.80(\log_{10}\rho_S) + 11.39 \tag{5}$$

$$\beta = 1.98(\log_{10}\rho_S) + 15.39 \tag{6}$$

The right side of equation (4) was obtained from experiments related to the distance L_1, the cleaning current I_C and the surface resistance ρs of the transfer belt **14**. In the experiments, the cleaning device **11** of the first embodiment shown in FIGS. **1** to **3** was used. As described before, in the first embodiment, the rotary member of the collection section **35** is the fur brush **37**, and the conductive member of the discharging section **36** is the conductive member **42**. The transfer belt **14**, which was made of polycarbonate, had a width W**3** (see FIG. **3**) of 350 mm and a film thickness of 150 μm. Also, the fur brush **37**, which was equipped with fur of conductive nylon, had an outer diameter of 15.4 mm, an axial direction or width W**1** of 310 mm and a resistance of 1×10^9 Ω. Further, the conductive brush **42**, which was equipped with fur of conductive nylon, had a fur length of 5 mm, an axial length or width of 310 mm and a resistance of 1×10^9 Ω.

First, the relation between the distance L_1 from the fur brush **37** to the conductive brush **42**, and the output voltage V_c of the constant-current d.c. power supply **43** was analyzed. Specifically, on cases where the cleaning current I_C was 5 μA, 10 μA, and 20 μA, the output voltage V_c was measured with the distances L_1 varied. FIG. **15** shows a measurement result in the case where the surface resistance ρs of the transfer belt **14** was 1×10^{10} Ω/□, and FIG. **16** shows measurement result in the case where the surface resistance ρs was 1×10^{11} Ω/□. In FIGS. **15** and **16**, the symbol "x" shows that a cleaning failure occurred. The cleaning failure was determined by the following manner. First, toner remaining on the transfer belt **14** after the passage through the cleaning device **11** was put onto adhesive tape. Then, concentration of the toner adhering on the adhesive tape was measured, where if the measured value was higher than a predetermined threshold value, it was determined as a cleaning failure.

Next, the relation between the surface resistance ρs of the transfer belt **14** and the output voltage V_c of the constant-current d.c. power supply **43** was analyzed. Specifically, on cases where the cleaning current I_C was 5 μA, 10 μA, and 20 μA, the output voltage V_c was measured with the surface resistances ρs varied. The distance L_1 from the fur brush **37** to the conductive brush **42** was 12.5 mm. A measurement result is shown in FIG. **17**. In FIG. **17**, the symbol "x" shows that a cleaning failure occurred, as in FIGS. **15** and **16**.

As a result of analyzing the measurement results of FIGS. **15** to **17**, it has been found that whether or not a cleaning failure occurs, conversely, whether or not the cleaning device **11** exerts proper cleaning performance depends on the output voltage V_c of the constant-current d.c. power supply **43**. More specifically, it has been found from the measurement results of FIGS. **15** to **17** that if the output voltage V_c of the constant-current d.c. power supply **43** is less than 5 kV, there occurs no cleaning failure regardless of the cleaning current I_C, the distance L_1, and the surface resistance ρs. Therefore, in FIG. **18**, the cleaning current I_C and the distance L_1 with which the output voltage V_c was 5 kV were plotted for cases where the surface resistance ρs was 1×10^8 Ω/□, 1×10^9 Ω/□, 1×10^{10} Ω/□, 1×10^{11} Ω/□, and 1×10^{12} Ω/□. In this FIG. **18**, for the cases that the surface resistance ρs was 1×10^{10} Ω/□ and 1×10^{11} Ω/□, the measurement results shown in FIGS. **15** and **16** were used. For the cases that the surface resistance ρs was 1×10^8 Ω/□, 1×10^9 Ω/□, and 1×10^{12} Ω/□, the output voltages V_c with the distances L_1 varied were similarly measured for the cases where the cleaning current I_C was 5 μA, 10 μA, and 20 μA to obtain the distances L_1 with which the output voltage V_c was 5 kV.

FIG. **18** include five graphs in correspondence to the values of the surface resistance ρs (1×10^8 Ω/□ to 1×10^{12} Ω/□). By determining an approximating curve by logarithm approximation with respect to each of these five graphs, the results of FIG. **18** are given by the following equation (7).

$$L_1=\alpha\cdot\log_e I_C+\beta \quad (7)$$

The factors α and β are defined by the equations (5) and (6) as described before. Equation (7) was obtained from the measurement results for the range of the surface resistance ρs of 1×10^8 Ω/□ to 1×10^{12} Ω/□. Accordingly, substituting ρs=1×10^8, 1×10^{12} into equations (5) and (6), respectively, yields a range of the factor α of −10.2 to −3.01 and a range of the factor β of 31.23 to 39.15. A variation of the factors α and β for the surface resistance ρs is shown in FIGS. **19** and **20**.

Equation (7) shows a condition under which the output voltage V_c is 5 kV, in other words, a condition under which a cleaning failure occurs due to that output voltage V_c becomes greater than or equal to the voltage. Consequently, the cleaning device **11** exerts the proper cleaning performance on condition that the distance L_1 between the rotary member (fur brush **37** or conductive roller **45**) and the conductive member (conductive brush **42**, conductive film **47** or fur brush **57**) is less than that of the right side of the equation (7).

FIG. **21** shows results of substituting 5 μA, 10 μA, and 20 μA as the cleaning currents I_C into equation (7) for the cases where the surface resistance ρs was 1×10^8 Ω/□, 1×10^9 Ω/□, 1×10^{11} Ω/□, 1×10^{12} Ω/□ and 1×10^{12} Ω/□. In a comparison of this FIG. **18** with FIG. **21**, it can be conformed that equation (7) adequately approximates the results of FIG. **18**.

The right side of equation (4) is then explained. Given a void t (mm) between two conductors and a void breakdown voltage V_B (V), Paschen's law is given by the following equation (8).

$$V_B=6200t+312 \quad (8)$$

Transforming this equation about the void t yields the following equation (9):

$$t=\frac{V_B-312}{6200} \quad (9)$$

Equation (9) shows a minimum void t at which void discharge does not occur between two conductors with respect to a given voltage. Accordingly, if the distance L_1 is larger than that of an equation obtained by replacing the void breakdown voltage V_B of the right side of equation (9) with the output voltage V_c, then void discharge does not occur between the rotary member (fur brush **37** or conductive roller **45**) of the collection section **35** and the conductive member (conductive brush **42**, conductive film **47** or fur brush **57**) of the charge-eliminating section **36**, thus allowing a closed circuit via the transfer belt **14** to be formed therebetween.

(Ninth Embodiment)

FIG. **22** shows an image forming apparatus according to a ninth embodiment of the invention. Whereas FIG. **22** depicts only part of the image forming apparatus of FIG. **1** for sake or explanation, the image forming apparatus of this embodiment has similar construction to that of the first embodiment shown in FIGS. **1** to **3**, except that the image forming apparatus of the present embodiment includes elements such as various sensors which will be described later. Therefore, although not shown in FIG. **22**, the elements illustrated in FIGS. **1** to **3** are also included in the image forming apparatus of this embodiment. In the following description, reference will be made also to FIGS. **1** to **3** in addition to FIG. **22**.

The constant-current d.c. power supply **43** of the cleaning device **11** includes a d.c. power supply **43***a* and a current sensing element **43***b* connected in series to the d.c. power supply **43***a*, and has a function of controlling the output voltage so that the current value of the cleaning current I_C is maintained constant. Further, the constant-current d.c. power supply **43** is enabled to set the cleaning current I_C to various values.

The primary transfer device **24** of each of the image forming units **16**A–**16**D has a conductive roller **24***a* opposed to the photoconductor drum **21** with the transfer belt **14** interposed therebetween. A regulated or constant-voltage power supply **101** is connected to the conductive roller **24***a*. A primary transfer voltage having a charging polarity (positive polarity) reverse to the normal charging polarity of the toner **30** forming a toner image on the surface of the photoconductor drum **21** (negative polarity in this embodiment) is applied to the conductive roller **24***a* by the constant-voltage power supply **101**. The constant-voltage power supply **101** includes a d.c. power supply **101***a* and a voltage sensing element **101***b* connected in parallel to this d.c. power supply **101***a*, and has a function of controlling the output current so that the primary transfer voltage is maintained constant. A semiconductive roller may be used instead of the conductive roller **24***a*.

A secondary transfer device **17** is equipped with a conductive roller **17***a* opposed to a stretching roller **14**B with the transfer belt **14** interposed therebetween. Similarly to the conductive roller **24***a* of the primary transfer device **24**, the conductive roller **17***a* is connected in series to a constant-voltage power supply **102** composed of a d.c. power supply **102***a* and a voltage sensing element **102***b* connected in parallel to this d.c. power supply **102***a*. The d.c. power supply **102***a* has a function of controlling the output current so that the voltage is maintained constant. A semiconductive roller may be used instead of the conductive roller **17***a*. Meanwhile, a stretching roller **13**B is grounded, and a secondary transfer current sensor **104** is interposed between the grounding portion and the stretching roller **13**B. There is formed a closed circuit from the constant-voltage power supply **102** to the grounding portion via the conductive roller **17***a*, the transfer belt **14**, the stretching roller **13**B, and the secondary transfer current sensor **104**. A secondary transfer voltage having a charging polarity (positive polarity) reverse to the normal charging polarity of the toner **30** forming a toner image on the surface of the transfer belt **14** (negative polarity) is applied to the conductive roller **17***a* by the constant-voltage power supply **102**. As a result of this, the toner image on the surface of the transfer belt **14** is transferred to the recording medium **28** that is passing through a nip portion formed between the transfer belt **14** and the conductive roller **24***a*. A current flowing through the closed circuit upon application of the secondary transfer voltage, i.e., a current flowing through the secondary transfer device **17** upon the application of the secondary transfer voltage (secondary transfer current I_{t2}) is detected by the secondary transfer current sensor **104**. The secondary transfer current sensor **104** outputs a detected value of the secondary transfer current I_{t2} to a controller **105**.

An environment sensor **106** is disposed inside the image forming apparatus. This environment sensor **106** senses a humidity H, and outputs a detected value to the controller **105**.

A sheet size sensor **107** for detecting the size of the recording medium **28** is disposed on the conveyance path between the sheet feed cassette **27** (see FIG. **1**) and the secondary transfer device **17**. The sheet size sensor **107** outputs a detected sheet size, i.e., a size of the recording medium **28** to the controller **105**.

Between the image forming unit **16**D located most downstream of the feed direction of the transfer belt **14** among the image forming units **16**A–**16**D, and the secondary transfer device **17**, there is disposed an AIDC (Auto Image Density Control) sensor **109**. The image forming units **16**A to **16**D form toner patches in regions ΔW (see FIG. **3**) where the recording medium **28** is not placed on the transfer belt. The AIDC sensor **109** detects the toner concentration at the toner patches, and outputs the detected values to the controller **105**.

A jam sensor **110** for detecting blockage or jamming of the recording medium **28** is provided within the image forming apparatus. This jam sensor **110** outputs to the controller **105** signals representing whether or not the jamming occurs.

The controller **105** equipped with such elements as CPU, RAM, and ROM adjusts the cleaning current I_C outputted by the constant-current d.c. power supply **43** of the cleaning device **11** based on inputs from the secondary transfer current sensor **104**, the environment sensor **106**, the sheet size sensor **107**, the AIDC sensor **109**, and the jam sensor **110**.

Next, the adjustment of the cleaning current I_C executed by the controller **105** is explained with reference to the flowcharts of FIG. **23**A and **23**B. First, given an image formation of a new job at step S**23**-**1**, then the cleaning current I_C is set to an initial value at step S**23**-**2**. Then, at step S**23**-**3**, a secondary transfer current I_{t2} is detected by the secondary transfer current sensor **104**. Specifically, a secondary transfer voltage is applied to the conductive roller **17***a* by the constant-voltage power supply **102** in the state that the recording medium **28** is absent at the nip portion between the conductive roller **17***a* and the transfer belt **14**, while a current flowing through the stretching roller **13**B is measured by the secondary transfer current sensor **104**.

With a small secondary transfer current I_{t2}, the toner **30** on the transfer belt **14** is scarcely affected by secondary transfer, having a tendency that the normal charging polarity (negative polarity) is maintained. In this case, since it is less required to invert the charging polarity of the toner **30** from reverse polarity (positive) to normal charging polarity by the cleaning device **11**, the cleaning electric field E_1 of the collection section **35** and the electric field E_2 of the charge-eliminating section **36** can be low in intensity. Accordingly, in the case of the small secondary transfer current I_{t2}, the cleaning current I_C can be a small current. On the other hand, with a large secondary transfer current I_{t2}, since the toner **30** of the transfer belt **14** is strongly affected by the secondary transfer, there is a tendency that the charging polarity is inverted to a polarity reverse to a normal charging polarity. In this case, it is necessary to uniformize the charging polarity of the toner **30** by setting the strength of the electric field E_2 of the discharging section **36** to a sufficiently high, and the electric field E_1 of the collection section **35** is preferably high as well. Accordingly, in the case of the large secondary transfer current I_{t2}, the cleaning current I_C needs to be large. Thus, if the detected value of the secondary transfer current I_{t2} is equal to or higher than a predetermined threshold value I_{t2th} at step S**23**-**4**, the set value of the cleaning current I_C outputted by the constant-current d.c. power supply **43** is increased by a predetermined quantity ΔI_{C1} at step S**23**-**5**.

Next, at step S**23**-**6**, a humidity H inside the image forming apparatus is detected by the environment sensor **106**. With a high humidity H, since the electrical conductivity of the sheet would increase due to moisture absorption, the transfer efficiency of the secondary transfer device **17** would tend to lower and the quantity of the toner **30** remaining on the transfer belt **14** would tend to increase. Thus, if the detected value of the humidity H is equal to or higher than a predetermined threshold value H_{th} at step S**23**-**7**, the set value of the cleaning current I_C is increased by a predetermined quantity ΔI_{C2} at step S**23**-**8**.

At step S**23**-**9**, a detected value of the sheet size sensor **107** is read in. With reference to FIG. **3**, since the width W**3** of the transfer belt **14** is wider than the maximum width W**2** of the sheet or recording medium **28**, areas ΔW not faced to the sheet are present on both sides of the transfer belt **14**. Ideally, toner does not adhere to these zones ΔW, but actually there occurs a phenomenon that the toner thinly adheres also to the zones ΔW (i.e., so-called toner fogging) at the primary transfer device **24** of each of the image forming units **16**A–**16**D. The smaller the sheet size is, the more the zones ΔW where the sheet on the transfer belt **14** is absent increase in area, resulting that the toner quantity tends to increase due to the fogging. Accordingly, in this case, there is a need for enhancing the toner collection efficiency by setting the cleaning electric field E_1 of the collection section **35** of the cleaning device **11** to a high strength. Conversely, the larger the sheet size is, the more the area of the zones ΔW decreases, resulting in that the quantity of residual toner due to fogging tends to decrease. In this case, the cleaning electric field E_1 of the collection section **35** is allowed to be relatively low in strength. Therefore, when sheet size detected by the sheet size sensor **107** at step S**23**-**10** is equal to or smaller than A4 size, the set value of the cleaning current I_C outputted by the constant-current d.c. power supply **43** is increased by a predetermined quantity ΔI_{C3} at step S**23**-**11**.

At step S**23**-**12**, an output of the AIDC sensor **109** is read in. As described before, the AIDC sensor **109** detects a toner concentration D in the toner patches on the transfer belt **14**. In the case where the detected toner concentration is high, toner concentration of the toner image on the transfer belt **14** is high so that a large amount of toner tends to remain on the transfer belt **14** even after the secondary transfer. Accordingly, in this case, there is a need for enhancing the toner collection efficiency by setting the cleaning electric field E_1 of the collection section **35** of the cleaning device **11** to a high strength. Conversely, in the case where the detected toner concentration is low, toner concentration of the toner image on the transfer belt **14** is low so that a small amount of toner tends to remain on the transfer belt **14** after the secondary transfer. Accordingly, in this case, the cleaning electric field E_1 of the collection section **35** can be relatively low in strength. Thus, if the detected value of the toner concentration D is equal to or higher than a predetermined threshold value D_{th} at step S**23**-**13**, the set value of the cleaning current I_C outputted by the constant-current d.c. power supply **43** is increased by a predetermined quantity ΔI_{C4} at step S**23**-**14**.

In the event that a jamming has occurred, the image forming apparatus comes to a halt while the toner image that has not been transferred to the recording medium **28** still remains on the transfer belt **14**. Therefore, since a large amount of toner has been remaining on the transfer belt **14** at a restart after occurrence of a jamming, i.e., at a first job after the occurrence of a jamming, there is a need for enhancing the toner collection efficiency by setting the cleaning electric field E_1 of the collection section **35** of the cleaning device **11** to a high strength. Thus, if the job is a first job after detection of a jamming by the jam sensor **110** at step S**23**-**15**, the set value of the cleaning current I_C is increased by a predetermined quantity ΔI_{C5} at step S**23**-**16**. In detail, the cleaning current I_C is increased temporarily only for at least a period that is required for the transfer belt **14** to make one turn after the start of the job.

After the completion of the processing shown in FIGS. **23**A and **23**B, the actual job is executed. The constant-current d.c. power supply **43** of the cleaning device **11** outputs the cleaning current I_C adjusted according to the charge amount and charge polarity of the toner remaining on the transfer belt **14** as well as on the amount of toner remaining on the transfer belt **14**. Therefore, the cleaning device **11** is enabled to exert proper cleaning performance and remove the toner remaining on the transfer belt **14** reliably and efficiently. For instance, the initial value of the cleaning current I_C and its control amounts ΔI_{C1} to ΔI_{C5} are set so that the cleaning current I_C is changed within a range from 3 μA to 50 μA.

The controller **105** may execute the control shown in FIGS. **23**A and **23**B not on the job basis but on the sheet or recording medium **28** basis.

Although the cleaning current I_C is adjusted in the control of FIGS. **23**A and **23**B, it is also possible to adjust the rotational speed of the fur brush **37** (rotary member) provided in the collection section **35** of the cleaning device **11**, more specifically the rotational speed of the motor **38**A that drives the rotation of the fur brush **37** as shown in FIGS. **24**A and **24**B. The faster the rotational speed of the fur brush **37** is, the higher the toner collection efficiency of the cleaning device **11** is. Conversely, the slower the rotational speed of the fur brush **37** is, the lower the toner collection efficiency of the cleaning device **11** is.

Given an image formation of a new job at step S**24**-**1**, then the rotational speed R of the motor **38**A is set to an initial value at step S**24**-**2**. If the secondary transfer current I_{t2} detected by the secondary transfer current sensor **104** at S**24**-**3** is equal to or more than a threshold value I_{t2th} at step S**24**-**4**, then the set value of the rotational speed R is increased by a predetermined quantity ΔR_1 at step S**24**-**5**. Subsequently, if a humidity H detected by the environment sensor **106** at step S**24**-**6** is equal to or higher than a threshold value H_{th} at step S**24**-**7**, then the set value of the rotational speed R is increased by a predetermined quantity ΔR_2 at step S**24**-**8**. Further, if a detected value of the sheet size sensor **107** read in at step S**24**-**9** is equal to or smaller than A**4** size at step S**24**-**10**, then the set value of the rotational speed R is increased by a predetermined quantity ΔR_3 at step S**24**-**11**. Further, if a concentration D of the toner patches detected by the AIDC sensor **109** at step S**24**-**12** is equal to or more than a threshold value D_{th} at step S**24**-**13**, then the set value of the rotational speed R is increased by a predetermined quantity ΔR_4 at step S**24**-**14**. If the job is a first job after detection of a jamming at step S**24**-**15**, then the set value of the rotational speed R is increased by a predetermined quantity ΔR_5 for at least a period that is required for the transfer belt **14** to make one turn at step S**24**-**16**.

After the completion of the processing shown in FIGS. **23**A and **23**B, the actual job is executed. The fur brush **37** provided in the collection section **35** of the cleaning device **11** rotates at a rotational speed adjusted according to the charge amount and charge polarity of the toner remaining on the transfer belt **14** as well as on the amount of toner remaining on the transfer belt **14**. Therefore, the cleaning device **11** is enabled to exerts proper cleaning performance and remove the toner remaining on the transfer belt **14** reliably and efficiently.

The adjustment of the cleaning current I_C (FIGS. **23**A and **23**B) and the adjustment of the rotational speed R of the motor **38**A (FIGS. **24**A and **24**B) can be applied in combination. The environment sensor **106** may detect the temperature inside the image forming apparatus in addition to or instead of humidity. In this case, the higher the detected temperature is, the larger the cleaning current I_C is set and the higher the rotational speed R of the motor **38**A is set. Conversely, the lower the detected temperature is, the lower the cleaning current I_C is set and the lower the rotational speed R of the motor **38**A is set. Further, the cleaning device **11** of the ninth embodiment may be of the construction adopted in the second to seventh embodiments (see FIGS. **7** to **14**). Also, the cleaning device **11** of the ninth embodiment may be so constructed that, as shown in FIG. **25**, the stretching roller **13**A opposed to the collection section **35** with the transfer belt **14** interposed therebetween is grounded without the provision of the discharging section **36**. Furthermore, the control of this embodiment can be applied also to the primary transfer device for the collection of the residual toner on the photoconductor

(Tenth Embodiment)

FIG. **26** shows an image forming apparatus according to a tenth embodiment of the invention. FIG. **26** depicts only part of the image forming apparatus of FIG. **1** for sake of explanation. The image forming apparatus of the tenth embodiment is similar in construction to that of the first embodiment shown in FIGS. **1** to **3**, except that the image forming apparatus of the present embodiment includes elements such as various sensors will be described later. Therefore, although not shown in FIG. **26**, the elements illustrated in FIGS. **1** to **3** are also included in the image forming apparatus of this embodiment. In the following description, reference will be made also to FIGS. **1** to **3** in addition to FIG. **26**.

The constant-current d.c. power supply **43** of the cleaning device **11** includes a d.c. power supply **43***a* and a current sensing element **43***b* connected in series to the d.c. power supply **43***a*, and has a function of controlling the output voltage so that the current value of the cleaning current I_C is maintained constant. A return current sensor **201** is provided between the discharging section **36** and the grounding portion. The return current sensor **201** outputs a detection value of a detected current (return current I_R) to a controller **203**.

The primary transfer device **24** of each of the image forming units **16**A–**16**D has a conductive roller **24***a* opposed to the photoconductor drum **21** with the transfer belt **14** interposed therebetween. A constant-voltage power supply **202** is connected to the conductive roller **24***a*. A primary transfer voltage V_{t1} having a charging polarity (positive) reverse to the normal charging polarity of the toner **30** forming a toner image on the surface of the photoconductor drum **21** (negative) is applied to the conductive roller **24***a* by the constant-voltage power supply **202**. The constant-voltage power supply **202** includes a d.c. power supply **202***a* and a voltage sensing element **202***b* connected in parallel to this d.c. power supply **202***a*, and has a function of controlling the output current so that the primary transfer voltage V_{t1} is maintained constant. Further, in this embodiment, the constant-voltage power supply **202** includes a current sensing element **202***c* connected in series to the d.c. power supply **202***a* so as to be able to control the output current so that the current becomes constant if required. In other words, the constant-voltage power supply **202** can function also as a regulated or constant-current power supply. A semiconductive roller may be used instead of the conductive roller **24***a*.

The controller **203** sets the primary transfer voltage V_{t1} of the primary transfer device **24** of each of the image forming units **16**A to **16**D. In particular, the controller **203** adjusts the primary transfer voltage V_{t1} of the primary transfer device **24** of the image forming unit **16**A, which is placed closest to the cleaning device **11** among the four image forming units **16**A to **16**D, according to the return current I_R.

In the cleaning device **11**, there is formed a closed circuit from the constant-current d.c. power supply **43** to the grounding portion via the scraper **41**, the collection roller **39**, the fur brush **37**, the transfer belt **14**, the conductive brush **42**, and the return current sensor **201**. A cleaning current I_C derived from the constant-current d.c. power supply **43** flows in this closed circuit. Therefore, the return current I_R and the cleaning current I_C are normally equal in value to each other. However, when the resistance of the transfer belt **14** has lowered due to endurance or when the humidity inside the image forming apparatus is high, there can occur inflow of a current into the cleaning device **11** from the primary transfer device **24** of the image forming unit **16**A that is placed closest to the cleaning device **11** among the four image forming units **16**A–**16**D. Occurrence of this inflow of a current would cause the return current I_R to become larger than the cleaning current I_C. More specifically, since the constant-voltage power supply **202** of the primary transfer device **24** controls the current so that the primary transfer voltage V_{t1} is maintained constant, decreased resistance would cause the current to become excessively large, and this excessively large current would flow into the cleaning device **11** via the transfer belt **14**. For example, if the return current I_R is 12 μA in spite of that that cleaning current I_C of 10 μA is outputted by the constant-current d.c. power supply **43** of the cleaning device **11**, it means that a current of 2 μA flows into the cleaning device **11** from the primary transfer device **24** of the image forming unit **16**A. If an excessive primary transfer current that has occurred at the primary transfer device **24** flows through the transfer belt **14**, the transfer belt **14** would be damaged, resulting in a shortened life. Therefore, the controller **203** decides the presence or absence of occurrence of the excessive primary transfer current at the primary transfer device **24** of the image forming unit **16**A from the value of the return current I_R, and adjusts the primary transfer voltage V_{t1} in the primary transfer device **24** of the image forming unit **16**A based on the decision.

The process executed by the controller **203** is explained in detail with reference to the flowchart of FIG. **27**. First, given an image formation of a new job at step S**27-1**, then a constant value of current flows simultaneously through the primary transfer devices **24** of the four image forming units **16**A–**16**D at step S**27-2**. Specifically, the constant-voltage power supply **202** of the primary transfer device **24** of each of the image forming units **16**A to **16**D is made to function as a constant-current power supply to output the current of constant value. Next, the primary transfer voltages V_{t1} outputted by the primary transfer devices **24** of the image forming units **16**A to **16**D is respectively measured by the voltage sensing element **101***b* while the constant-value current is passing therethrough at step S**27-3**. The primary transfer voltages V_{t1} measured at the primary transfer devices **24** are outputted to the controller **203**. At step S**27-4**, a set value for the primary transfer voltage V_{t1} of each of the image forming units **16**A to **16**D to be used in the actual image formation is determined based on the measured primary transfer voltages V_{t1}. Specifically, since set values for the primary transfer voltage V_{t1} corresponding to the primary transfer voltages V_{t1} measured at step S**27-3** are stored in the controller **203** in the form of a table, the set values of the primary transfer voltage V_{t1} for actual image formation are uniquely determined to the measured values of the primary transfer voltage V_{t1}.

An excessive primary transfer current that occurs at the primary transfer devices **24** of the image forming units **16**B to **16**D almost fully flows into adjacent other image forming units, thus hardly contributing to increase in the return current I_R. Therefore, the primary transfer devices **24** of these image forming units **16**B–**16**D are used for the image formation without adjusting the set values of the primary transfer voltage V_{t1} determined at step S**27**-**4**. Meanwhile, with respect to the image forming unit **16**A placed closest to the cleaning device **11**, the set value of the primary transfer voltage V_{t1} is further adjusted at steps S**27**-**5** to S**27**-**9**.

First, at step S**27**-**5**, the primary transfer voltage V_{t1} set at step S**27**-**4** is applied to the primary transfer device **24** of the image forming unit **16**A. Specifically, a voltage outputted by the constant-voltage power supply **202** of the primary transfer device **24** is taken as the set value of the primary transfer voltage V_{t1}. Then, at step S**27**-**6**, a return current I_R under the condition that the primary transfer device **24** is outputting the set value of the primary transfer voltage V_{t1} is detected by the return current sensor **201**. At step SS**27**-**7**, If the detected value of the return current I_R is equal to or higher than a predetermined threshold value I_{Rt}, i.e., if it is decided that an excessive primary transfer current generated by the primary transfer device **24** of the image forming unit **16**A is flowing into the cleaning device **11**, then the set value of the primary transfer voltage V_{t1} determined at step S**27**-**4** is decreased by a predetermined quantity ΔV_{t1}. The process of steps S**27**-**5** to S**27**-**8** is repeated until the detected value of the return current I_R becomes less than threshold value I_{Rth} at step S**27**-**7**. At step S**27**-**7**, if the detected value of the return current I_R is less than the threshold value I_{Rth}, then the primary transfer voltage V_{t1} corresponding to the return current I_R is established as the set value of the primary transfer voltage V_{t1} of the image forming unit **16**A at step S**27**-**8**.

After the completion of the process shown in FIG. **27**, the actual job is executed. The primary transfer voltage V_{t1} outputted by the constant-voltage power supply **202** of the image forming unit **16**A has been adjusted so that excessive primary transfer current flowing into the cleaning device **11** is not generated. Accordingly, inflow of the excessive current into the transfer belt **14** can be prevented, resulting in that the service life of the transfer belt **14** can be prolonged.

The controller **203** may execute the control shown in FIG. **27** not on the job basis but on the sheet or recording medium **28** basis.

The cleaning device **11** of the tenth embodiment may be of the construction adopted in the second to seventh embodiments (see FIGS. **7** to **14**). Also, the cleaning device **11** of the tenth embodiment may be so constructed that, as shown in FIG. **28**, the stretching roller **13**A confronting the collection section **35** with the transfer belt **14** interposed therebetween is grounded without the provision of the charge-eliminating section **36**. In this case, the return current sensor **201** is provided between the stretching roller **13**A and the grounding portion.

The present invention is not limited to the foregoing embodiments, and may be modified in various ways. For example, the core metal **37***a* (see FIG. **2** and FIGS. **7** to **11**) of the fur brush **37** of the collection section **35** or the core metal (see FIG. **6**) of the conductive elastic roller **45** may be connected directly to the constant-current d.c. power supply **43**. Also, a metallic roller may be used as the rotary member of the collection section **35**.

Conductive rubber may be used instead of the conductive brush **42** (see FIGS. **2**, **6**, **8**, and **11**), the conductive film **47** (see FIGS. **7** and **10**), and the fur brush **57** (see FIG. **9**). The conductive brush **42**, the conductive film **47**, and the fur brush **57** may be grounded via a resistor. Adjusting the resistance value of the resistor allows the present invention to be applied to transfer belts have various resistance values and characteristics.

Further, when the normal charging polarity of the toner is reverse to the foregoing embodiments, i.e. positive, the polarity of the voltage applied from the constant-current power supply to the collection section **35** or the discharging section **36** is reversed. For example, if the normal charging polarity of the toner is positive in the first embodiment, it is appropriate to connect the scraper **41** to the negative terminal of the constant-current d.c. power supply **43**.

Further, the present invention may also be applied to the cleaning device of the intermediate transfer drum or the photoconductor of the photoconductor drum or the like.

Furthermore, the present invention may also be applied to cleaning devices for image bearing bodies provided in other image forming apparatuses such as copying machines, facsimile devices and multi-function machines in addition to laser printers.

Although the present invention has been fully described in conjunction with preferred embodiments thereof with reference to the accompanying drawings, various changes and modifications are possible for those skilled in the art. Therefore, such changes and modifications should be construed as included in the present invention unless they depart from the intention and scope of the invention as defined by the appended claims.

What is claimed is:

1. A cleaning device for collecting toner on a surface of an image bearing body, comprising:

a rotary member having electrical conductivity and being rotatively driven while being in contact with the surface of the image bearing body;

a conductive member which makes contact with the image bearing body on an upstream side of the rotary member in a conveyance direction of the image bearing body; and

a single d.c. power supply to which one of the rotary member and the conductive member is connected, the other being grounded, and which generates a d.c. current that flows via the image bearing body between the rotary member and the conductive member, whereby a first electric field in such a direction as to exert a force for adsorbing the toner of a normal charging polarity to the rotary member is generated between the rotary member and the image bearing body while a second electric field in a direction reverse to the first electric field is generated between the conductive member and the image bearing body.

2. A cleaning device as claimed in claim **1**, wherein the rotary member is connected to the d.c. power supply and the conductive member is grounded.

3. A cleaning device as claimed in claim **1**, wherein the d.c. power supply is a constant-current d.c. power supply.

4. A cleaning device as claimed in claim **1**, wherein the direct current I_c (μA) flowing between the rotary member and the conductive member via the image bearing body, an output voltage V_c (V) of the d.c. power supply, and a distance L**1** (mm) from a contact position of the rotary member with the image bearing body to a contact position of the conductive member with the image bearing body in the conveyance direction of the image bearing body satisfy the following relation:

$$\frac{V_c - 312}{6200} < L_1 < \alpha \cdot \log_e I_c + \beta,$$

where α and β are factors related to surface resistance of the image bearing body.

5. A cleaning device as claimed in claim **4**, wherein the factor a is between or equal to −10.2 and −3.01.

6. A cleaning device as claimed in claim **4**, wherein the factor β is between or equal to 31.23 and 39.15.

7. A cleaning device as claimed in claim **1**, further comprising a second conductive member which contacts with the image bearing body on an upstream side of the conductive member in the conveyance of the image bearing body and is grounded.

8. A cleaning device as claimed in claim **1**, further comprising a third conductive member which contacts with the image bearing body on a downstream side of the rotary member in the conveyance direction of the image bearing body and is connected to the d.c. power supply.

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